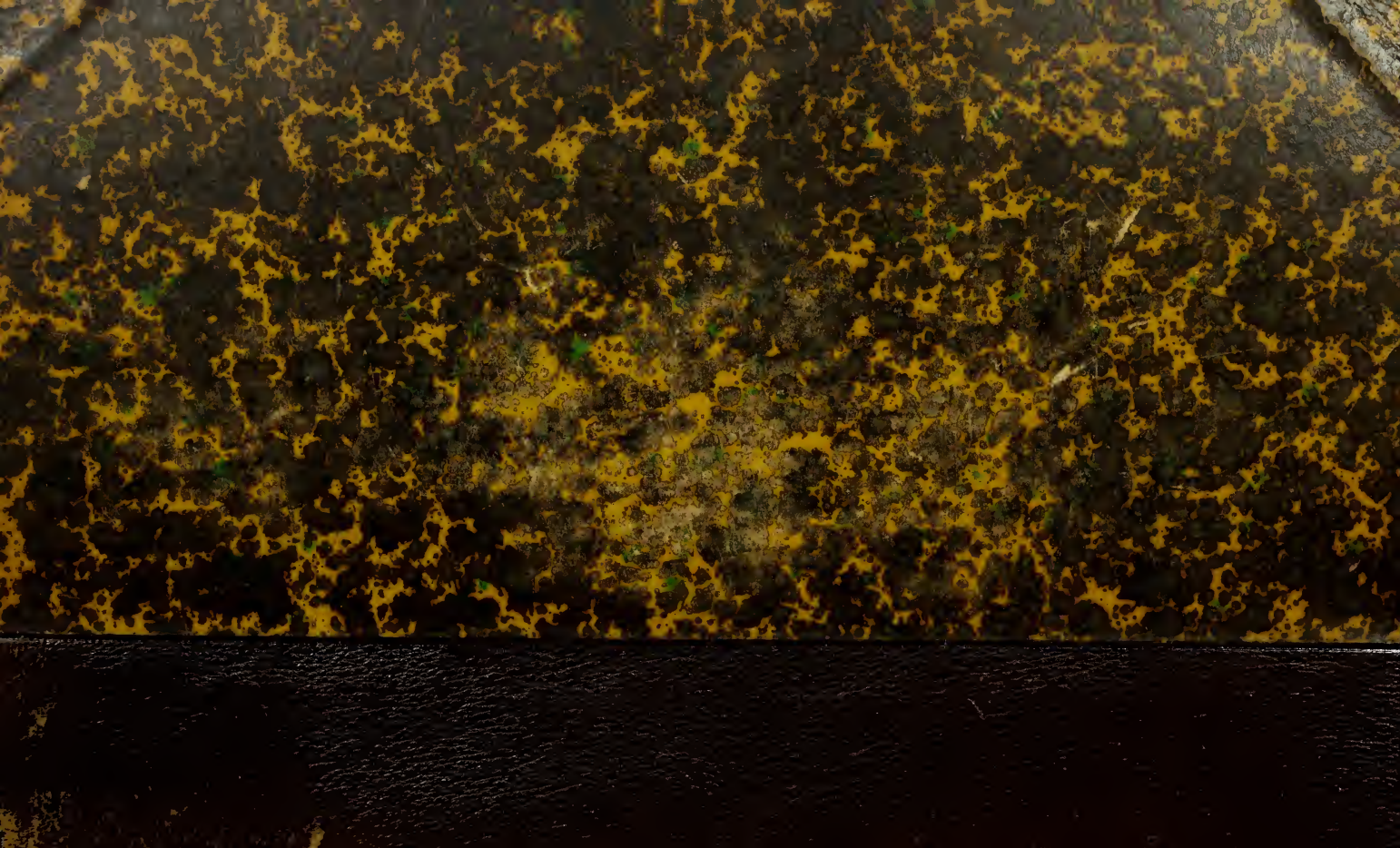

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TRANSACTIONS

OF THE

CIVIL AND MECHANICAL ENGINEERS' SOCIETY.

(Founded May 1859.)

44th SESSION 1902—1903.

EDITED BY

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THE

Civil & Mechanical Engineers Society.

(Founded May 1859.)

47 VICTORIA STREET, WESTMINSTER, LONDON, S.W.

(Telephone, 244, Victoria).

SESSION 1902–1903.

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The Society is indebted to the Editor of *The Mechanical Engineer* for the loan of the blocks for illustrating the following papers :—

"Indicating High-Speed Steam Engines," by A. Marshall Arter, A.M.I.C.E.

"The Production of Power by means of Gas Producers and Engines," by R. W. A. Brewer, A.M.I.C.E.

"A Description of a few of the most recent Water Turbine Plants in Great Britain and Abroad," by Alph. Steiger, M.I.C.E.

And to the Editor of *The Iron and Coal Trades Review* for the loan of the blocks illustrating the paper on "Recent Experiments with Centrifugal Fans," by W. Gilbert, Wh.Sc., A.M.I.C.E.

Civil and Mechanical Engineers' Society.

TRANSACTIONS—SESSION 1902-3.

PRESIDENTIAL ADDRESS,

By Mr. C. T. A. Hanssen, A.M.I.C.E.

[Read before the Society on November 6th, 1902.]

RUSSIAN ENGINEERING WORKS AS A PROFITABLE INVESTMENT FOR BRITISH CAPITAL.

Having spent the greater part of the present year in Russia, and having had opportunity to study the condition and prospects of this vast Empire, it seems natural to me, on the present occasion, when you have done me the honour to elect me the President of this Society, to devote my Presidential Address to the consideration of the engineering relations between this country and the Russian Empire.

Having had to write this address while in Russia, and being unable to refer to the necessary documents, I cannot say anything about the prospects of this Society, but must leave this to our Hon. Secretary, whose energy and perseverance have done so much to bring it to its present condition, and who, I trust, will long continue to conduct the affairs of this Society with the same ability as he has done hitherto.

The popular joke which attributes the cheerful countenance of a Christian martyr on a certain well-known picture, where he is about to be thrown before the lions, to the fact that he will "not have to make an after-dinner speech," applies with still greater force to the man who has to deliver a Presidential Address, as all the subjects generally dealt with in such addresses have been rehearsed so often, and by so many eminent men, that it is almost impossible to say

anything, either in the way of retrospect of the present state, or to give a forecast of the future state of Engineering without repeating what has already been said by others.

With regard to Russia, however, I venture to think it possible to say a great deal that is new to most people in this country, where Russia is very little known and generally considered as a sink of iniquity, where there is neither law, justice, nor honesty, and where bribery and corruption flourishes exceedingly.

The present greatness of the Russian Empire is generally dated from the battle of Pultarva, 1709, where the great Warrior-king of Sweden, was defeated by Peter the Great. I would go a few years further back, and date Russia's greatness from the battle of Narva, when 80,000 Russians were defeated by 5,000 Swedes, but where the unconquerable spirit of the great Tsar showed itself by his remark after the battle—"*We have still got a great deal to learn.*" He lost no time in lamenting such a dreadful calamity, which in the eyes of all the rest of the world put a final end to Russia's aspirations, but began at once learning how to conquer.

The words of Peter the Great may still be considered the motto of modern Russia. She still admits she has got a great deal to learn from Western Europe, but she desires to learn slowly. In a large and sparsely populated country like Russia the spread of education and the eradication of ancient prejudices and errors must, of necessity, proceed slowly, and no government in the world, not even the most powerful, can in the long run, with impunity, defy the prejudices of the vast majority of her subjects and Russia cannot therefore always progress at the same pace as the rest of Europe, but substantial progress is nevertheless made, and the Russian Government is doing its utmost to reform abuses, prevent corruption, and to improve education, and it is therefore to be hoped that those who have the above-mentioned opinion about Russia will see their way to modify it considerably.

That the present fiscal policy of Russia, with its enormous import duties on every manufactured article, has done much to hinder the development of trade, and to embitter the feeling of England against Russia, cannot be denied, and also in Russia it begins to be understood that this policy is inimical to the interest of Russia, that a policy that prevents import must, of necessity, also prevent export, and that the high import duties really favour the manufacturing interest at the expense of the agricultural interest, which latter, in Russia, is of far greater importance than the former, and that the rational policy of Russia at present would be to develop her agriculture, and to accept from a highly-developed industrial country like England the products of her mines and workshops in exchange for the agricultural products, which cannot be sold at good prices at home.

From Russian official reports it appears that the peasants generally have holdings of four to seven acres, and that these

holdings are considered too small, that they are badly cultivated, that the land is being exhausted from lack of manure, and that the average nett earnings of a Russian peasant by sale of his surplus produce only amount to about £5 to £6 per year. The peasants therefore are compelled to leave their farms, to be managed by their wives and children, and go to the nearest town, where they manage to live and send money home, on wages that seldom exceed 1s. 6d. per day.

Of the total population of Russia 87½ per cent. live in the country, chiefly as peasants, and only 12½ per cent. in the towns. Over 80 per cent. of the Russian exports are products of agriculture, and it will therefore be seen how greatly Russian agriculture needs some of the fostering care now lavished on industry.

The bulk of the workmen employed in the factories and mines are peasants, that return to their farms for the harvest, and stop there till the following Spring, when they migrate to the towns. They are therefore, as may be expected, neither good farmers nor good workmen, although as a rule they are willing and intelligent, but lack the early and constant training, and being poorly fed are not capable of any great exertion, and that therefore, in spite of the low wages paid in Russia, the cost of production for manufactured articles is quite as high or higher than in England, and only made profitable by the high prices due to import duties.

Russia therefore is not likely to compete successfully in foreign markets, as far as industrial products are concerned, but in her own market all such drawbacks are compensated for by import duties, amounting to from 20 to 150 per cent. of the value of the imports. Cast-iron pipes, for instance, that are generally sold for £6 per ton in England, have to pay a duty of £5 18s. in Russia. With freight and duty English pipes cannot be obtained below £13 per ton, and the Russian price is almost exactly the same as the English in the seaport towns.

It is evident production under such conditions must be very profitable, and it is therefore no wonder that a great number of English, German, and Belgian manufacturers have elected to build factories within the charmed circle of Russian custom-houses, but as the Russian Government is a firm believer in something like a Monroe doctrine for Russia, she has made the condition that no firm can obtain Government contracts when more than 2 per cent. of their employees are foreigners, and also stipulates that two-thirds of the Directors of the Company shall be Russians. Judging however from the number of foreign companies that flourish in Russia these conditions cannot be very onerous, and it is only a fair equivalent for the enormous advantages of a protective tariff that Russia should obtain a body of workmen, trained in the workshops established by foreign capital, which within the protected area, can cater for the requirements of 130,000,000 Russian subjects, under an artificial increase of value amounting to as much as 100 per cent.

In order to get the full value of this increase a good deal of discrimination is necessary. An engineering factory having to buy its raw material, for instance, will find that the raw material has absorbed the greater part of the extra profit, because it is itself protected, but ironworks producing iron from their own mines prosper amazingly. The New Russia Company, in the South of Russia, have paid 15 per cent. interest on their capital for the greater part of the time they have been established, and have in addition written off the whole of their capital three times over, and accumulated a large reserve fund. This is not the only successful works in British hands, thread mills and naphtha mines have also been very prosperous ; in fact, with one exception, almost all British enterprise in Russia has been at least fairly successful.

The one exception forms the Odessa Water Works. Here a certain gentleman, about the year 1870, secured a Concession from the Town Council of Odessa, giving him the right to build waterworks and supply the town with water on certain stipulated terms. As he did not intend to supply the capital himself, but merely to sell the Concession, he was not very particular about the terms, and readily agreed to anything proposed by the Town Council. One of the terms was that the company should supply all the water required by the Town Council, and by the Russian Government, free of charge, without naming any limit to the amount of water thus supplied.

Under ordinary conditions no responsible financier would ever have given money to build water-works under a Concession containing such a clause, but the notorious Baron Grant was then in the height of his prosperity, and could float any company he chose to put on the market, and he bought this Concession, found the capital, and the works were eventually started.

It did not take long for the Odessa Town Council to find out the great value of cleanliness when it could be obtained for nothing. They were not content to water the streets, they were imitating Paris and had the streets washed every night, flooding them with water. The sewers were also kept scrupulously clean by using vast quantities of flushing water. The Russian Government were equally extravagant, and the Waterworks Company began to feel that they had made a bad bargain. Every effort to introduce a clause for limiting the supply of water used free of charge failed, and at last the Company were glad to sell the Works to the Corporation at a great loss.

It is doubtful whether a company working under such an agreement would have fared much better in any other part of the world. Town Councils are not generally adverse to take full advantage of hard contracts, and the Odessa Town Council, which is, as I am informed, to a great extent, composed of Greeks, Jews, Armenians, and other extremely sharp business men, could hardly be expected to show much mercy to a water company, as such companies rarely

manage to become popular however much they minister to the comfort of the public.

Another mistake made by the Odessa Waterworks Company was that their concession was only a private agreement made with the Town Council instead of an act passed through the Ministry of the Interior, which would have been equivalent to an English Act of Parliament. If an act passed by the Russian Government had contained such an absurd clause as the Odessa Waterworks Concession this might have been rectified by an appeal to the Government, but a private agreement can, in Russia, as in England, only be altered with the consent of both parties. We need only imagine an English company offering to build waterworks for Manchester or Liverpool without an Act of Parliament and under a private agreement with the Town Council to understand the difficulties of the position, and the extreme carelessness with which British investors will risk their money on the strength of one or more high sounding names on the prospectus.

It is highly important in doing business in Russia to understand all the various conditions of the country thoroughly. These are in most respects essentially different from those in England. Although Russia certainly must be considered a highly civilised country, fully able to take its place among other European countries, it should not be forgotten that this civilisation has not been produced by the efforts of individuals as in England, but by the direct action of the Government. All energy and enterprise seems still to be centred in the Government, and the average Russian, instead of trusting to his own energy and to private enterprise, has during the last two centuries been accustomed to look to Government as a kind of Providence that must do everything. He is, as it were, walking with Government crutches, and seems to collapse when the crutches are taken away.

This however is not to be considered a reproach to the individual Russian, for we find in every country that the first advance in civilisation is due to foreign influence, and not to a spontaneous generation of civilisation in the country itself. England is now civilising India and Egypt, but the proud commercial and industrial pre-eminence she holds is distinctly due to the Dutch and Huguenot imigration in the 17th and 18th century, caused by the religious persecutions of Philipp II. and Louie XIV., and these imigrants in their turn only transferred the civilisation of Italy and Greece to England.

In the same way Russia now, in order fully to develop her immense resources, needs not only the capital, but also the individual character and energy developed in Western Europe, and specially in England. There is no lack of learned men, clever professors, poets, painters, doctors and officers. The Civil Service, although it has got a bad name for bribery and corruption, is probably not by any means so black as it is sometimes painted.

When we consider that this service has a vast responsibility, and handles enormous sums of money, and that the superior officials in it are paid salaries ranging from £100 to £300 a year, in a country where every article except house rent and food is very much more expensive than in England, we can hardly wonder at the irregularities that take place, and must admit that even this service is fairly efficient. If the system of business in the Russian Government offices could only be simplified this evil of bribery and corruption might be met by reducing the number of officials, and paying the remaining ones higher salaries.

The great want of Russia however seems to be practical and reliable leaders, with character enough to resist the prevailing social and moral corruption, and ability to gain the confidence of the lower classes. Such men are scarce in all countries, but more especially in Russia, where all educational training is purely academic, and where almost all work is performed under the deadening influence of Governmental routine, and where every official is like a wheel in a big machine, moving according to precedent and orders, but seldom taking any individual responsibility. In Russia an engineer who designs defective works can be sent to prison, but I have not heard of any special reward for designing good works, so that the inducement to do anything else than copying existing works as closely as possible does not exist, and each official is anxious to let his superior bear all the responsibility, and as the last resource those that cannot escape responsibility shield themselves behind standard text-books, chiefly German, in which the Russians have great faith.

For these reasons it is not advisable merely to subscribe money to Russian undertakings, it is absolutely necessary that works built with English capital should be under English management, and that really competent men of high moral character should be placed in positions of trust in the management of such works.

The field open to the profitable investment of capital in Russia is simply enormous. The Russian Empire is two-and-a-half times larger than the United States, and has nearly twice as many inhabitants, and if only the Russian Government could see her way to meddle as little as possible with the private affairs of her subjects, there is no reason why Russia should not be one of the richest and most prosperous countries in the world.

There is no doubt that the Russian Government is animated by the best intentions, and earnestly desires to make Russia happy and prosperous, but the methods used for effecting this are unfortunately not those that have proved successful in other countries, and certainly not those of *laissez faire laissez aller*, which have proved such a blessing to the rest of Europe.

For every one however that keeps strictly within the rules laid down by Russian law, minds his own business, accepts the political, moral and religious opinion, which the Government supplies ready-

made, and in a suitable variety, to everyone of her subjects, and has his passport duly labelled, stamped and revised at proper times. The Government is a very benevolent depotism, which does its utmost to foster every industry and every undertaking that might prove of advantage to the community, and although the Russian law courts are extremely slow, there is not the slightest suspicion of corruption among the Russian judges, that have to judge all matters to a value of more than 50 roubles.

The most important branches of engineering which are open to British capital and industry are the following :—

1. Mines and Minerals.
2. Irrigation Works.
3. Municipal Works.
4. Factories.

1. The mountains that fringe the Russian Empire in Europe, namely, the Ural, the Caucasian, and the Carpathian Mountains, together with the districts adjoining them, are on the whole very rich in valuable minerals. The Ural Mountains especially are exceedingly rich. There is hardly any known metal or mineral not to be found in this vast region in enormous quantities. The development of these mining resources is hindered chiefly by want of proper railway communications with the rest of Russia, and with the vast coalfields of the Tomsk district, where the world's largest known coalfield exists, extending over an area of 26,000 square miles, and containing seams of coal from 40 to 140 ft. thick, of many varieties, and of excellent quality. These coalfields are practically untouched, and so are the enormous deposits of iron and copper in the Ural Mountains, where whole mountains of the finest hematite ore are found, and where copper ore also exists in large quantities, and of which I have seen specimens containing 56 per cent. of metallic copper, and where the owners of the mines are willing to guarantee an average yield of 43 per cent. in large quantities of ore.

The coalfield is about 400 miles from the nearest part of the new Siberian Railway, and the district is as yet a wilderness. The lowest freight from the point where the Siberian Railway crosses the Ural Mountains to St. Petersburg is £2 13s. 3d. per ton, so that it is prohibitive for coal or iron ore, and only suitable for more valuable products. It cannot, however, last long before this favoured district must develop into an important industrial centre, chiefly for supplying the fertile and formerly densely populated areas in Central Asia, as Sir-Daria, with the important town of Taschkent, Samarkand, Khiva, Bokhara, which district now contains over 5,000,000 inhabitants, and has all the conditions for becoming a rich and highly civilised country. It has an area nearly 49 times larger than that of the British Isles, with a climate

similar to that of Spain and Italy, extending as it does from the 35th to the 46th degree of latitude from the Equator, and it would certainly be able to maintain an enormous population if it were properly developed. The country still bears abundant marks of former civilisation, as it formed part of the Persian Empire, and is watered by the Rivers Oxus and Jaxartes so often mentioned in ancient history.

In the southern part of Russia, near Odessa and Nikolaiev, are large deposits of hematic iron ore of excellent quality and great purity which may be made available for support.

2. The great need of Southern Russia and Central Asia is irrigation works. The Summer here is hot and dry, and the scorching East winds will sometimes wither a promising harvest in a few days. Unfortunately the Russian rivers, like those of South Africa, dry up, or at least run very low during the Summer, and in many parts the natural obstacles to irrigation will probably be too great to make the works remunerative. In other parts, however, such works can be built without any great engineering difficulties, and as land in nearly all parts of Russia can be bought for about £6 per acre, it will be possible to buy land and increase its value many times over by building works, and obtain a large revenue by letting irrigation lands to tenant farmers.

In Central Asia there are large areas, especially in the valleys of the rivers Oxus and Jaxartes, where ancient irrigation works are still in existence, and the neglect of these works is the reason of the present poverty of the inhabitants. They are, however, being repaired and improved by the Russian Government, and the land is being slowly planted and developed, but capital is required for doing this on a large scale.

By properly developing these countries Russia may one day have a possession, with a population which, if the country should only be half as densely populated as England and Wales, would amount to 165,000,000 souls. The official statistics give the area of the six provinces of Central Asia, viz., Ferghana, Samarkand, Sir-Daria, Transcaspia, Khiva, and Bokhara, as 590,000 square miles. Out of this area 59,000 square miles are fertile river valleys, within reach of irrigation from the large rivers. Another 59,000 square miles are oases, that can be watered from canals or smaller rivers; 236,000 square miles have fertile soil, and may be available for artificial irrigation, but as the rainfall in Central Asia barely exceeds 9 in. per annum, no cultivation is possible without irrigation. The remaining 236,000 square miles are either high, snow-clad mountains, from which the two important perennial rivers Oxus and Jaxartes spring, or they are barren sand wastes, incapable of cultivation, but the 354,000 square miles capable of cultivation may be developed into unthought of prosperity if the Russian Government will allow English capital and enterprise to take full advantage of the natural resources of the country.

Unfortunately the Russian policy in such matters is very short-sighted, and interposes all kinds of petty restrictions and regulations, with the view of securing the full advantage of these countries to her own subjects, and although there is nothing in these restrictions to prevent the investment of English capital, they will probably greatly limit the inflow of capital while they are in force.

3. *Municipal Work.*—The Russian Empire contains 105 towns with over 20,000 inhabitants, and a very large number of provincial towns and villages with over 10,000 inhabitants. Of these towns two, namely, St. Petersburg and Moscow, have over one million inhabitants, five have over 250,000, twelve over 100,000, forty over 50,000, and forty-six over 20,000. Only about one-half of these towns have got any public water supply, and only (four) towns have got any proper sewerage system, namely, Moscow, Warsaw, Odessa and Kieff. Russian Town Councils, as a rule, have no desire to undertake such works at their own expense, and as matters stand at present it would probably be very unwise to entrust them and their officials with the large sums of money needed for such purposes.

On the other hand it is extremely difficult to raise capital for forming companies to do such work in Russia, as the only class of people with money to invest are the merchants and manufacturers, and such people either invest their money in their own business or want the highest security, such as can only be obtained in Government loans or by mortgages on real property. Such securities in Russia pay from 4½ to 7 per cent. interest, so that the prospect of high dividends does not tempt the Russian investor as long as they involve the slightest element of risk. Although, therefore, many of the Russian Joint Stock Companies pay 20 to 30 per cent. interest per annum, they are almost, without exception, financed by English, French, German or Belgian capitalists. Three large thread and cotton mills in St. Petersburg, employing over 4,000 workmen, are under English management, and the enormously profitable petroleum industry is nearly all in the hands of the Swedish firm of Nobel.

The Russian nobility, which was once the wealthiest in Europe, is now almost as poor as the planters in the Southern States of America, and the Russian peasants, whose emancipation in 1865 has ruined the nobility, have yet to learn the proper use of their liberty, and they have certainly no surplus capital to invest in Joint Stock Companies.

It is therefore comparatively easy to obtain really valuable concessions for municipal work in Russia, and to work them profitably as limited companies with English capital. If these companies are either over-capitalised or utilised for giving comfortable situations to otherwise useless friends and relations of the directors, like a great many of the French and Belgian companies in Russia, it stands to reason that they cannot be made to pay good

dividends, but honestly formed and well managed companies of this kind can reckon with certainty on dividends from 10 to 15 per cent. on the capital.

4. The value of factories in Russia depends almost entirely on the Russian Custom Tariff, which fluctuates a good deal according to the necessity of raising revenue, and the demands from the various interests clamouring for protection, and a close study of the tariff is essential for success in manufacturing. All factories dealing with staple products, such as iron, wool, cotton, wine, beetroot sugar, and other articles in common use, are almost sure to be profitable if not too grievously mismanaged. The profits in these trades are however so large that they will pay handsomely in spite of a certain amount of mismanagement and peculation, but under really good management the profits are amazing. The Petersburg Cotton Mills are returned as giving 30 per cent. interest, but as they form part of an international trust the actual profits obtained in Russia may be still larger, as the import duty on cotton yarn is £112 per ton, and the import duty on the raw material is only £20 8s. per ton, and the workmen only get nine to ten shillings per week. There can therefore be no doubt that the profits must be very large, but in this line it would not be wise to compete, as the present trust is rich enough to ruin all intending competitors, and in fact began the business in Russia by ruining the then established firms.

It will give me sincere satisfaction if my remarks this evening should have the effect of awakening some interest in the development of Russia, and in putting before English capitalists the great scope there is in that country for the profitable employment of their capital.

SOME ENGINEERING FEATURES OF THE GARDEN CITY SCHEME.

By Ebenezer Howard.

Author of *Garden Cities of To-morrow*.*

[Read before the Society on October 2nd, 1902.]

Before commencing to read this paper I desire to make a short explanation. The original date fixed for its reading was the 6th November, but quite recently—and when not a line of it had been written, and only its general features had presented themselves to my mind, I was asked to read it on the 2nd October. This in a rash moment I consented to do. I do not, however, put this circumstance forward it as an excuse for the many imperfections of the paper, but rather as accounting for the *supposed* knowledge of engineering questions which as a layman I may possibly *seem* to display in this paper; for, feeling as I did very keenly the difficulty of the task I had undertaken, I was impelled to seek the advice and assistance of several well-known engineers, and the paper which I shall now read is the fruit of assistance generously rendered me by Mr. G. R. Strachan, Mr. James Swinburne, Mr. George Beilby, Mr. F. L. Rawson, and Mr. A. S. E. Ackermann, instead of being the more crude attempt which longer time for preparation might have lured me into making.

The Garden City project is the outcome of much thought directed to the solution of two problems which are in reality, one—overcrowding in our great cities and depopulation of our rural districts, and it should therefore attract the attention of all persons who are concerned—and who among us is not concerned? in the well-being of our country and of the race. But though the Garden City method of solving the housing problem and the problem of agricultural depression should be of interest to all (for if these problems are not soon solved then the best days of England are over) that method should be of special interest to the Engineering profession. And this for two reasons. First because the proposals of the Garden City Pioneer Company

* Swan Sonnenschein & Co., Garden City Association, 347 Birkbeck Bank Chambers, W.C. Post free, 1s. 3d.; cloth, 1s. 9d.

are based upon a few very elementary Engineering propositions—propositions so simple indeed that they have been almost lost sight of and needed apparently a man who was not an engineer to show their great bearing upon these great social problems ; and, secondly because if the Garden City method is a sound one—and those who believe it are steadily growing in numbers—then a vast field of engineering enterprise will soon spread itself before the members of your profession in a way which will tax, as I imagine you delight to have taxed, your skill and resources—especially when these can be profitably directed to large social ends.

What is the Garden City project? Putting it very shortly, it is a project for building an entirely new town of the most up-to-date character, and for building that new town on a new area ; and my main contention is that, given a suitable site, the skill of engineers and other experts can be so wisely, and so economically directed to its systematic development, that capital, energy, skill, industry and population are sure to be attracted to that area ; because the best results can then be secured at the least cost ; and thus the line of least resistance will be found for industrial and social force.

Perhaps the best way of giving you an insight into the essential principles which I conceive should be adopted in building such a town, will be to describe a purely imaginary one. But if I do this I hope you will not therefore consider either myself or those who are co-operating with me as bound by the details I may give, because these obviously cannot be settled until a site is actually secured, nor can they be evolved except by the collaboration of many experts united in one common purpose—that of building a town which shall avoid many of the evils which our present towns exhibit, and shall secure advantages which can never be secured except where skill and capital is untrammelled to any considerable extent by man's former efforts or by vested interests.

With this understanding, I may describe Garden City as a town, with a population of about 30,000 ; occupying 1,000 acres, surrounded by its own agricultural estate of 5,000 acres. The first of the essential principles which Garden City stands for is, that just as every well-planned house has its own Garden, so every well-planned town should be surrounded by a belt of open country —a belt never to be built upon no matter how the city may grow. Diagram No. 6 shows the principle of growth which the city should adopt when the 1,000 acres are built up and the city desires to expand. This diagram supposes that the Garden City has reached its limit of population. How then will it grow without departing from the principle just laid down of preserving a belt of open country? It will grow by establishing—under Parliamentary powers probably—another city some little distance beyond its zone of country, so that the new town may have a country zone of its own. I have said "by establishing another city," and for administrative purposes there might be two cities; but the

inhabitants of the one could reach the other in a very few minutes; for rapid transit would be specially provided, and thus the people of the two towns would in reality represent one community. And this principle of growth—this principle of always preserving a belt of country round our cities—would be ever kept in mind till, in course of time, we should have a cluster of cities, not of course arranged in the precise geometrical form of my diagram, but so grouped round a Central City that each inhabitant of the whole group, though in one sense living in a town of small size, would be in reality living in, and would enjoy, all the advantages of a great and most beautiful city; and yet all the fresh delights of the country; field, hedgerow and woodland—not prim parks and gardens merely—would be within a very few minutes walk or ride.

This then is the first essential principle the Garden City stands for—combined town and country life for all the people of England.

The second essential principle is, that in laying out our town we should provide ample recreative spaces within it, and should also secure that each house or cottage should occupy a *minimum* space of say, 20 ft. by 100 ft. Thus does the Garden City represent the hope—nay, the firm belief—that we, the people of this 20th century have come to recognise overcrowding is not a necessity of civilisation, but a terrible blot upon it, which blot it must be our business to completely erase.

The next essential principle which the Garden City stands for, is that towns need planning quite as much as houses do. Garden City is therefore planned as a whole, and planned under the best expert advice. Possibly if the contours admitted of it, the plan I now exhibit might be a suitable one. Here the town is of circular form with a diameter of about 1½ miles.

Six magnificent boulevards—each 120 ft. wide—traverse the city from centre to circumference, dividing it into six equal parts or wards. In the centre is a circular space containing about five-and-a-half acres laid out as a beautiful and well-watered garden; and, surrounding this garden, each standing in its own ample grounds, are the larger public buildings, town hall, principal concert and lecture hall, theatre, library, museum, picture-gallery and hospital.

The rest of the large space encircled by the "Crystal Palace" is a public park, containing 145 acres, which includes ample recreation grounds within very easy access of all the people.

Running all round the Central Park (except where it is intersected by the boulevards) is a wide glass arcade called the "Crystal Palace" opening on to the park. This building is in wet weather one of the favourite resorts of the people, whilst the knowledge that its bright shelter is ever close at hand, tempts people into Central Park, even in the most doubtful of weathers. Here manufactured goods are exposed for sale, and here most of that class of shopping which requires the joy of deliberation and selection is done. The space enclosed by the Crystal Palace is,

however, a good deal larger than is required for these purposes, and a considerable part of it is used as a Winter Garden, the whole forming a permanent exhibition of a most attractive character, whilst its circular form brings it near to every dweller in the town, the furthest removed inhabitants being within 600 yards.

Passing out of the Crystal Palace on our way to the outer ring of the town, we cross Fifth Avenue—lined, as are all the roads of the town, with trees—fronting which, and looking on to the Crystal Palace, we find a ring of very excellently built houses, each standing in its own ample grounds; and, as we continue our walk, we observe that the houses are for the most part built either in concentric rings, facing the various avenues (as the circular roads are termed), or fronting the boulevards and roads, which all converge to the centre of the town. Asking the friend who accompanies us on our journey what the population of this little city may be, we are told about 30,000 in the city itself, and about 2,000 in the agricultural estate, and that there are in the town 5,500 building lots of an *average* size of 20 ft. by 130 ft.—the minimum space allotted for the purpose being 20 by 100. Noticing the very varied architecture and design which the houses and groups of houses display—some having common gardens and co-operative kitchens—we learn that general observance of street line or harmonious departure from it are the chief points as to house-building over which the municipal authorities exercise control, for, though proper sanitary arrangements are strictly enforced, the fullest measure of individual taste and preference is encouraged.

Walking still towards the outskirts of the town, we come upon "Grand Avenue." This avenue is fully entitled to the name it bears, for it is 420 ft. wide, and forming a belt of green upwards of three miles long, divides that part of the town which lies outside Central Park into two belts. It really constitutes an additional park of 115 acres—a park which is within 240 yards of the furthest removed inhabitant. In this splendid avenue six sites, each of four acres, are occupied by public schools and their surrounding play-grounds and gardens, while other sites are reserved for churches, of such denominations as the religious beliefs of the people may determine, to be erected and maintained out of the funds of the worshippers and their friends. We observe that the houses fronting on Grand Avenue have departed (at least in one of the wards—that of which Diagram 3 is a representation)—from the general plan of concentric rings, and in order to ensure a longer line of frontage on Grand Avenue, are arranged in crescents—thus also to the eye, yet further enlarging the already splendid width of Grand Avenue.

On the outer ring of the town are factories, warehouses, dairies, markets, coal yards, timber yards, &c., all fronting on the circular railway which encompasses the whole town, and which has sidings connecting it with the main line of railway which passes through the

estate. This arrangement enables goods to be loaded direct into trucks from the warehouses and workshops, and so sent by railway to distant markets, or to be taken direct from the trucks into the warehouses or factories; thus not only effecting a great saving in regard to packing and cartage, and reducing to a minimum loss from breakage, but also, by reducing the traffic on the roads of the town, lessening to a very marked extent the cost of their maintenance. The smoke fiend is kept well within bounds in Garden City; for all machinery is driven by electric energy, with the result that the cost of electricity for lighting and other purposes is greatly reduced.

While the town proper, with its population engaged in various trades, callings, and professions, and with a store or depot in each ward, offers the most natural market to the people engaged on the agricultural estate, inasmuch as to the extent to which the townspeople demand their produce they escape altogether any railway rates and charges; yet the farmers and others are not by any means limited to the town as their only market, but have the fullest right to dispose of their produce to whomsoever they please. Here, as in every feature of the experiment, it will be seen that it is not the area of rights which is contracted, but the area of choice which is enlarged.

This principle of freedom holds good with regard to manufacturers and others who have established themselves in the town. These manage their affairs in their own way, subject, of course, to the general law of the land, and subject to the provision of sufficient space for workmen and reasonable sanitary conditions. Even in regard to such matters as water, lighting, and telephonic communication—which a municipality, if efficient and honest, is certainly the best and most natural body to supply—no rigid or absolute monopoly is sought; and if any private corporation or any body of individuals proved itself capable of supplying on more advantageous terms, either the whole town or a section of it, with these or any commodities, the supply of which was taken up by the corporation, this would be allowed. No really sound system of *action* is in more need of artificial support than is any sound system of *thought*. The area of municipal and corporate action is probably destined to become greatly enlarged; but if it is to be so, it will be because the people possess faith in such action, and that faith can be best shown by a wide extension of the area of freedom.

I will now deal, but of course not in detail—for that would be impracticable till a site is selected—with some of the engineering features of Garden City, which, though designed as a whole, would of course be carried out on the instalment principle.

A first essential of life is water; and the water engineer who would be consulted as to the selection of the site would, if it were on water-bearing strata, indicate the positions of the wells and storage reservoirs, and arrange from the outset that a protective area be

secured round his wells to guard against pollution. If the water were best obtainable from upland sources he would have to determine where he got the raw water, how and where to store it, and where to filter it. He would then study the configuration of his site to secure the best lines for distribution : and as the whole city will be planned out before he has to lay a pipe, he will be able to adjust his reticulation system to known conditions in a manner which rarely if ever falls to the lot of the water engineer.

The question of sewage disposal would then have to be considered, for it would be the duty of the sewage engineer to convey the soiled water, after domestic and business use, to the disposal site, and to design works which would restore it to a condition for discharge into the streams if the site was inland, or into a tidal estuary or the sea without offence if the site was riparian or on the coast. For once in his life the sewage engineer would be happy. He would take care that those parts of the site that were too flat or too low-lying were excluded from business or building purposes which produce sewage, and indicate that their natural use was for parks, plantations, allotments or such like. It would not be necessary for him to strain engineering devices in order to gravitate the sewage, for he would see that the town was adapted to a reasonable and proper gravitation system before a house was built or a business started. In laying out his sewers he would choose Nature's lines, and thus secure economy and efficiency. He would also have the advantage of knowing beforehand how the town would develope, and, like the water engineer, he would be able to adjust his sewers with unexampled precision to their work. Many of my friends suggest that the true method of dealing with excreta and soiled water is to apply it directly to the land, and Dr. Vivian Poore has shown by actual experiment many of the advantages that undoubtedly follow such a method. But even granting that this is the best system, would not an attempt to force upon a community so radical a change in their method of life be unwise ; and would it not be easily possible to so arrange matters that if a number of enthusiasts of this system come forward, as seems very probable, they should have a part of the town allotted to them where they might deal with this thorny question after their own fashion, and if they are right they might be certain their method would spread ?

From the electrical supply point of view the Garden City presents no difficulties. Electrical power would be required for lighting, for business and manufacturing purposes, for public trams, for private electric motors, for lifts and ventilators, for public buildings and large houses, for lathes and small machines, used for trade and households. Among the first uses to which the electric power would be put would be the supply of energy and light to the various works in progress, *i.e.*, in the construction of the town itself. This demand would of course pass away gradually, but it would be replaced by the ordinary demands of a thriving town. If

the city were to be built to-morrow, steam engines would probably be used for generating electrical energy, and in that case the station would be outside the town, in a place where there is water for condensing, and where coal can be brought by rail or canal. On the other hand, if the city is started in a year or two from now, it is likely that gas engines will be used for this purpose, and the electric power station would then be a handsome building in the centre of the city, sending forth its energy like the very sun! But whether the power station used steam engines or gas engines a considerable quantity of warm water would be produced, in the one case by condensing, and in the other by cylinder cooling. This suggests that the public baths, wash-houses and laundries, should be situated near the power station, so as to make use of the warm water. The waste heat could also be used for drying in the case of the laundries.

Lighting would probably be partly by gas of a poor quality with incandescent mantles, especially in the streets, and as the same gas could be used for cooking and warming there would be no smoke, and there need be no household coal. In houses it is probable the electric light would be most popular, and with the very high load factor which may be expected, it should be cheap.

The distribution of energy, water, heat, light, gas, telegraph and telephone wires, pneumatic tubes for parcels delivery, the removal of sewage, and possibly even house and street refuse, would be enormously facilitated, and consequently cheapened, by a thorough system of subways. These subways, instead of being completely and solidly covered in, might be made with less than the usual headway, but with moveable covers, so as to be readily accessible from the roadway.

The traffic on the roads would, as I have already shown, be quite different to that of the ordinary town; and it is difficult to say whether electric tramways would be advisable where roads are wide, distances small, surfaces good, and electric motor cars available. Probably there would be electric cars on some of the radial avenues, running right out into the more distant country, while some of the streets will probably be arranged for rapid transit, and by carrying them under or over the slower-traffic streets where they intersected, the engineer would secure a novel and advantageous feature. Garden Cities ought therefore to specially attract the Motor Car industry.

In Garden City a large development of the Distributing Kitchen system may be expected; people will frequently send their boots out to be cleaned; clothes will be much looked after on the valetry system: gas fires will do away with much household drudgery, and one or two servants will be able to manage a large house.

Mr. Troup, C.B., head of the Parliamentary Department of the Home Office, gave evidence recently to the effect that the relief of congested districts might be met by the removal of factories to the

country. He stated that the number of factories in London which employed over 100 persons was 748, the total number of employees being 200,000, and that this, with the wives and families would represent a total population of 600,000. How can you as engineers doubt your ability to offer these factory owners great inducements to leave the crowded city, thus benefiting alike those who move and those who remain behind? Surely you cannot. The advantages to an industrial community, of having light, heat and power "on tap" at practically wholesale prices are so obvious, that the supply is bound to produce a demand. Then too, not merely these commodities themselves, but also the best means and appliances for using them, can be placed within their reach; furnaces, ovens, and other heating apparatus, motors, cranes and ventilating appliances —all of these may be of the very best of their kind. And when the absolute fundamentals of industry are provided without thought or care on the part of the ordinary user, will not his mind be left entirely free for the development of his own particular branch of handicraft or industry. Surely then, there is in what I have laid before you, scope for your ingenuity, not hitherto available, which ought if fully used, to create a city with every advantage at a minimum of cost; and that being so, the very law of supply and demand leads me confidently to affirm that Garden Cities are the cities of To-morrow.

Let me now deal with a quite distinct branch of engineering, as to which I am gaining actual experience through my efforts to realise in a concrete form what has been an abstraction in my mind for some years. How are we to engineer such a scheme as I have suggested: how are we to carry it out?

Now the first stage in the realisation of an idea, for the carrying out of which a large band of able workers is required, is to get a great many people to know of it, to think well of it, to desire it, to work for it. To this end some machinery is usually required. In the present case that machinery was found in the formation of the Garden City Association, which took place in June, 1899. This Association has done good work; it has served to make the project somewhat widely known, and it has about 1,400 members.

The next stage was the formation of a Company—called the Garden City Pioneer Company, a Company with a capital of only £20,000—obviously quite insufficient for the carrying out of the great task which lies before us; but sufficient for the end which that Company was formed to achieve—namely, to secure the option of a suitable estate, of course under the best expert advice; to prepare a scheme for its development—again of course under the best expert advice, and to enter upon negotiations with manufacturers, co-operative societies, building societies, private residents and others with a view to their settlement upon the estate. That Company is now an accomplished fact, for though the prospectus very properly told those to whom it was issued that

they must not regard the taking of shares in this Pioneer Company as an investment, for it was possible the scheme would not go through; and although if the scheme did go through all the shareholders would receive would be shares in the new Company of equal value with shares in the old, together with interest at 4 per cent—yet, thanks to a very large amount of free advertising (the generous contribution of the fourth estate to the project) three-fourths of the capital have been subscribed or promised;* further shares are being steadily taken up; the Company, which has a Board of Directors which includes several highly successful business men, is proceeding with its task, and in the course of a short time a grand scheme—for it will be the outcome of many expert minds—will be prepared, and then the public will be confidently asked to subscribe the large sum which will be necessary in order to carry out an undertaking which is certain to result in great National benefits.

I ought before concluding this paper to point out that the large Company which is to be presently formed will expressly limit its dividend, and will make provision for its undertaking being bought out by the inhabitants of the town after say seven or ten years. For it is intended to adopt as an essential feature the principle of securing the increment of land values for the people of Garden City, with a view to creating a fund out of which the cost of public undertakings may be defrayed. Nothing is more certain than that the conversion of agricultural land into urban land will be attended with a large rise in value, and this by being invested upon the estate must enhance enormously the security of the original investors. Thus the limitation of dividends to reasonable dimensions will actually operate to the advantage of investors, and the project, if wisely and skilfully carried out, will demonstrate conclusively that the more wide are the social aims of public companies, the more absolutely secure are the investments they offer. Our great Railway Companies at the outset made the cardinal mistake of not catering properly for the masses; of despising the third-class passengers: let us on the other hand lay out a city in the interests of all classes, and then an investment of the most stable character will be secured. Seek ye first the well-being of the people, and all other things shall be added unto you.

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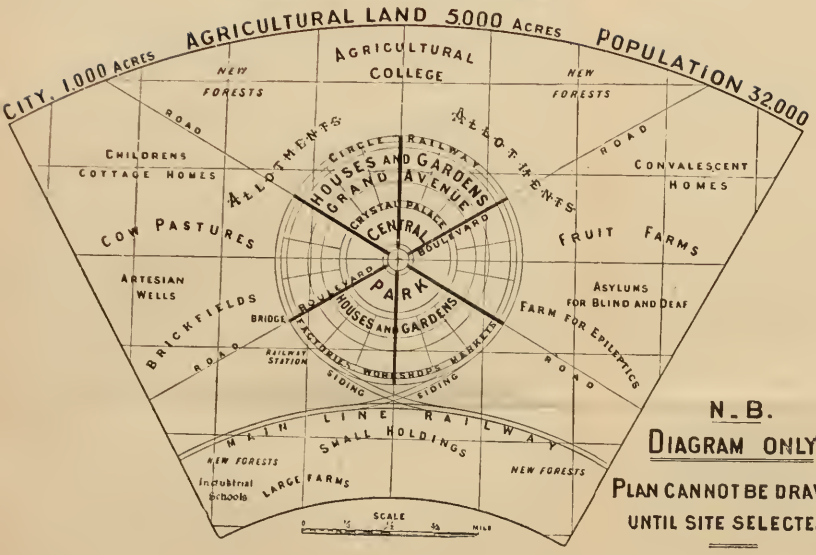
* Soon after the reading of this paper the whole of the capital was subscribed, and a public announcement will shortly be made as to the site selected.

ARD A
RDG
CITY, 1.000
EVA
GRA
TREET
FROEBEL
CYCLE W

— Nº 2 —

GARDEN - CITY



N.B.
DIAGRAM ONLY.
PLAN CANNOT BE DRAWN
UNTIL SITE SELECTED

WARD AND CENTRE

Nº 3.

GARDEN - CITY

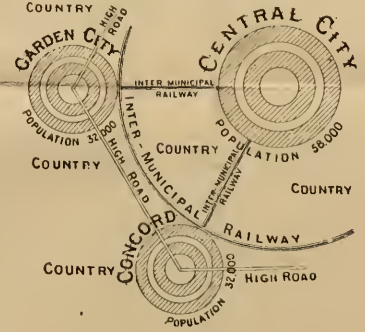
N.B.
A DIAGRAM ONLY.
PLAN MUST DEPEND UPON
SITE SELECTED.

Nº 4.
— ADELAIDE —

SHOWING PARK LANDS ALL ROUND CITY, AND ITS MODE OF GROWTH.

Nº 5.
— DIAGRAM —

ILLUSTRATING CORRECT PRINCIPLE OF A CITY'S GROWTH - OPEN COUNTRY EVER NEAR AT HAND, AND RAPID COMMUNICATION BETWEEN OFF-SHOOTS



SOME NOTES ON TUNNELLING.

By A. E. Rogers, M.A., A.M.I.C.E.

[Read before the Society on Thursday, December 4th, 1902.]

The author feels that in taking the place of the Vice-President of the Society at short notice he is substituting a very inferior paper for that which would otherwise have been read, and must apologise for the small amount of personal experience which he has had of the subject.

Firstly, the question will arise, why should a tunnel be constructed at all, before we have to deal with the method by which it shall be constructed, and here most engineers will agree that it is not advisable to tunnel in any case where with approximately the same expenditure the desired result can be accomplished by other means.

As in all other cases of the design of public works, the question of cost is now one of the main considerations, and if it is impossible to arrange a line in the open air without raising this cost to an impossible figure, or interfering disastrously with the purpose for which the line is intended, it may be necessary to resort to a tunnel; but wherever open cuttings can be substituted they will in the long run prove the more satisfactory method of carrying the line.

A good example has lately occurred on the South Eastern and Chatham Railway of the danger and difficulty of doubling a tunnel, and it is probable that if the engineers originally responsible for the tunnel at Chislehurst had taken the bull by the horns and made a cutting instead, their successors would have had a far easier task when the increasing traffic made it necessary to double the line. As it is, a large part of the old tunnel has been cut right out and open air work substituted; and from the shallow depth of this cutting now it seems probable that it must have been more the consideration of the cost of the land above than any fear that the work would be unmanageably deep, which must have originally caused the making of the tunnel, although no doubt the cost of excavation previous to the invention of the steam navvy and other labour-saving machines must have made deep cuttings a much more comparatively expensive item in railway construction than they now are.

Tunnels almost always cost more than is expected. It is impossible even with the greatest care and with most elaborate

experiments to foresee exactly what difficulties may occur, or how much bad ground or water may be found; the construction of them owing to the darkness and obstacles encountered is most difficult to efficiently supervise or inspect; and the maintenance of the permanent way through them is more costly and dangerous than in the open.

Before anything more than a rough estimate of the cost of any tunnel can be made, it is necessary to ascertain as nearly as possible the nature of the ground through which it will pass; and in doing this, although the geological surveys of most thickly populated countries will give a good idea of the general formations likely to be met with, nothing but trial will really show how much allowance will have to be made for those minor faults and imperfections in the strata, which are the most general sources of serious trouble in construction.

Every effort should be made in arranging the position and alignment of a tunnel to avoid striking or following a fault or cleavage line in the strata, as this will very frequently introduce materials into the line of tunnel quite different from the surface formations; and water, which is the greatest source of trouble in all earthwork, is very likely to be found in such a position.

When, as frequently happens, a tunnel is required to join two lines of railway running up subsidiary valleys on either side of a dividing ridge of hills, it should be borne in mind that these valleys, in all probability, owe their formation to the action of water eroding the loosened and shattered ground in the immediate vicinity of a fault in the strata, and the tunnel should be located in the sound and undisturbed material to one side or other of this fault; or the geological formation known as an "anticlinal fold," which, being originally an upheaval of the ground surface, is the last thing that would, without due consideration, be expected to be the cause of a depression, may have introduced into the line of the tunnel strata of a much lower formation than those showing on the hillsides to right and left.

It is therefore necessary to find out as closely as possible what ground may be expected, and for this purpose either borings may be made or shafts may be sunk. Wherever possible the latter plan should be adopted, as the information gained from shafts is much fuller than can be expected from borings. Not only the nature of the material, but the amount of water in and the pressure exerted by it can be ascertained, and as in most cases these shafts can be afterwards used for the construction of the tunnel, the difference in their cost as compared with borings is compensated for.

In some cases, of course, even this precaution will not prevent unpleasant surprises. In the well-known Kilsby tunnel on the London and North Western Railway, then known as the Birmingham and London Railway, which was finished in 1838, the pocket of running sand, which gave such an amount of trouble, was,

unfortunately, not touched by any of the trial holes made. In Smiles' *Life of George Stephenson*, the amount of water raised 120 ft. from this bed is said to have averaged 2,000 gallons per minute during eight months of the progress of the works.

In the great tunnel now being constructed under the Simplon Pass, the vein of crushed marble, from which is flowing an enormous stream of water under high pressure, could not of course be detected beforehand, owing to the nature of the mountain above; but this affords an excellent example of the extraordinary and unforeseen difficulties which may be encountered in tunnelling, when it is considered that the tunnel had been driven for miles through the hardest forms of rock, such as quartz, gneiss, and micacious schists, and that this much later formation, evidently open above in some way to the drainage of the snowfields, was struck right in the heart of the mountain, where it might certainly have been expected to find nothing of the kind.

In has been possible in some cases to run a heading right through on the line of the tunnel, and where this is done the future cost of the work can be accurately allowed for, but it is very inadvisable to resort to anything of the kind in uncertain ground. In the long tunnel at Catesby, on the Great Central Railway, owing to a difficulty in obtaining access to the land above, it was found necessary to run a bottom heading from a point about three chains north of the north face to connect with the northernmost shaft, and more trouble was experienced in keeping this heading open, and afterwards in completing the tunnel in this section than in any other part of the work. This particular length happened to lie in the Capricornus zone of the Lower Lias, which proved of a more treacherous nature than the Lower Margaritatus zone, through which most of the remainder of the tunnel ran.

In the majority of cases the first proceeding on the commencement of the actual construction of a tunnel is the sinking of as many shafts as may be necessary and expedient, having regard to their depth and cost, and the time within which it is necessary to finish the work. It is seldom possible, except in very steep or mountainous ground, to commence driving at either face, as these are generally situated in deep cuttings, which have to be previously excavated, and as a tunnel, if of any length, is one of the most important and slowest works on a line, it should be started as soon as possible. The material raised from the shafts can either be run down to bank at either end, or, as is more frequently the case, be put into spoil heaps near the mouths of the shafts.

From these shafts driving is then began in both directions, thus giving two working faces to each shaft.

A certain number of the shafts will probably be left permanently open for purposes of ventilation, and these will be lined with brickwork, while the temporary shafts, lined with timber, will be carefully filled in again after they are done with.

In any formation in which the strata lie approximately horizontal, more trouble from water is likely to be met with in the shafts than in the tunnel itself, owing to the greater number of beds cut through, and wherever any considerable flow of water is found, which, if neglected, would ooze through the shaft lining, and cause a drip into the tunnel, some such method as that at Catesby may be adopted. Here an annular brick collecting chamber was built round the back of the lining at the lower side of the water-bearing beds, and the ground made solid below it; the water was then conducted through the shaft ring and down the shaft by means of pipes into the main tunnel drain. One such flow was used to supply water by gravitation to the station at the south or upper end of the tunnel.

The most usual method adopted in England, and now extensively employed elsewhere, in driving a tunnel in which timbering is required, is that known as the "English system," which can be shortly described as follows:—

The first excavation got out is that for the "Top heading," in which are set the two main "Crown bars." The heading is then widened on either side alternately, until the whole of the six main roof timbers or "Drawing bars" are in place, and the timbering is completed to the level of the "Top sill." The excavation is then carried down to the level of the "Lower sill," on which the "top sill" is supported by underpinning props. Rakers are placed to stiffen the sills against the face of the excavation, which in loose ground is close boarded. The excavation is then carried down again to the required depth. This operation is carried on generally in lengths of from 12 to 15 ft., but in bad ground 10 ft. is often done, and in very good ground, on the straight, 18 ft. By this method the whole of the length is left quite clear for the bricklayers, who put in first the invert in cases where one is required, then the sidewalls, and finally the arch itself.

The timbering of the sidewalls is removed as these rise, but in very bad ground it is sometimes found necessary to leave in the poling boards. Thus in the majority of cases the same timber can be used again. When the lowest of the six "Drawing bars" is reached, the space below it, outside the arch, is bricked in tight; as the arch rises, 9 in. walls are built between the bars, from the extrados to the poling boards, to support these latter when the bars are drawn forward, and when the bars are in their new position, the spaces formerly occupied by them are packed tight with brickbats to prevent any settlement of the ground above. The bars now rest with their back-ends on the finished brickwork of the completed length, on wedge blocks known as "badgers," and their leading ends supported on small or "nipper" props in the heading in front. The next length is then ready for excavation.

The height at which the crown bars must be set above the finished line of the work is generally a matter for experience as the

work proceeds, and depends of course on the amount which the pressure from above forces them down. In the heavy ground at Catesby they came down as much as 2 ft. in some cases, and if they are not set sufficiently high to allow of this movement, they have to be shaved to admit of the full brickwork going in, and so have to be left *in situ*, and the difficult and costly operation of getting a new set of bars down the shaft and into position, the avoidance of which is one of the chief merits of the English system, has to be undertaken.

In cases where the ground is sufficiently good to admit of the construction of a bottom heading, extra working faces can be got by means of "break ups" from this, and in fairly sound ground, especially where the shafts are very deep, or there is any difficulty in disposing of the excavated material from them, this method is often adopted, and the material run away through the heading to the end of the tunnel.

In the tunnel extension of the Liverpool Overhead Railway, where the ground above is residential property, the shafts were only used for the construction of such a heading, and the tunnel itself excavated from twelve break-ups from this. This tunnel is in loosish rock, not exerting any great pressure.

When working a tunnel like this from a bottom heading one of the problems which requires most careful thinking out is the removal of the material from the excavation, and the running in of the bricks required for the lining, without the trains blocking each other. In a double line tunnel of large size it is of course always possible to provide passing places wherever a sufficient length of finished tunnel is available, and thus arrangements can be made by which very little time is wasted, but in constructing a single line it is extremely difficult to so arrange matters as to proceed with any proper speed. The author was a short time ago engaged in looking after the completion of a tunnel in the South of Ireland for a single line of railway of 3 ft. gauge, and ventures to give here some description of this work, hoping that it may prove of interest.

The tunnel is a little over 500 yards long, and commences at the northern end on a curve of 20 chains radius.

The part remaining to be driven consisted of a length of straight in continuation of work already complete, and a curve of 10 chains radius, opening to the south and ending in a short piece of cut and cover, one length of which, at the face, was already in. Owing to the ground above being very broken and steep, impeded by both houses and heavy timber, it was impossible to get any accurate results with chain measuring, and it was necessary to fix the tangent points of the 10-chain curve by triangulation. Work was started from both ends, the cut and cover at the south being extended as far as was possible, and a heading about 8 ft. by 9 driven from the north in the tunnel.

This work from the north was an unavoidable necessity owing to

the exigencies of time, for there was no possibility of disposing of the material got up, except by hauling up a shaft, and this was a very slow business; also owing to the gradient falling towards the south it was necessary to pump the water from the working end continually to avoid flooding the miners. As it was these latter kept the floor too high, and it had afterwards to be lowered before any lining could be begun.

The rock through which this tunnel is driven is a metamorphic sandstone, lying in beds of thicknesses varying from 9 in. or a foot to layers like rotten slate. The bedding is very distorted, but on the whole lies mostly perpendicular, with the backs at an angle to the line of the tunnel, constantly altering owing to the curve on which the latter runs.

The rockdrills were driven by compressed air, supplied from compressors by Messrs. Thos. Larmuth & Co., and the holes were drilled nearly straight into the face during the excavation of the heading. The amount of Nobel's gelignite used per cubic yard of rock got in this heading was about $2\frac{1}{2}$ lbs., but of course when the widening out of the tunnel was proceeding, and the roof being blown down the proportion of rock to explosive was much larger. Driving was begun on November 5th, and the headings met through 444 ft. on the afternoon of January 28th, about 70 working days, during which time also about 30 ft. of cut and cover at the south end had been put in. The error of the centre line, working from two ends of a 10-chain curve, was $\frac{5}{8}$ in.

The next proceeding was to widen out the heading to the full section, as the rock was found sufficiently sound to admit of this being done without any danger of falls before the lining was put in.

Now commenced the organisation difficulty, to which reference was made before.

Being very much pressed for time, it would have been most desirable, if it had proved possible, to arrange to start the work at more than the two ends, but owing to the small size of the tunnel, only 16 ft. wide by 16 high unlined, it was found that the heaps of stuff blown down at either end could not be cleared away in time to admit of any wagons being run in and out to any central point.

The plan therefore adopted was to use the heap of rock at either end as a platform on which to plant the drills, and so a heap of broken rock, representing practically the amount blown down by one series of shots, was kept always moving forward, so that miners could work on the top of it with the drills, while another gang cleared as much of the tail of the heap as could be got away before the next blow. This clearing away was a very slow business, as the lumps of rock were frequently large and heavy, and the wagons used at the south end were too large to admit of two of them being loaded at one time except by putting in a pin road from the top of the heap. Each wagon when loaded had then to be run out to the mouth of the tunnel by hand and an empty run in.

Had the contractor seen his way to treat the tunnel like a mine drift and use skip wagons with a loading dock outside the tunnel, the stuff might possibly have been got away quicker, as two roads could have been laid, on the system adopted in the tube railways; but there was a difficulty in getting plant to the spot as it had to come from Scotland, and there was therefore never any opportunity of comparing the relative speed of the two systems.

The water also which should have run out at the south end of the tunnel was blocked back by the heaps of fallen rock, and the intermediate space between the two faces was therefore not the most comfortable place to work in.

After the whole of the rock had been got out the lining had to be put in. This was composed of concrete sidewalls with a brick in cement arch of eliptical section three rings thick; and here again the small size of the hole made the supply of materials a very troublesome business. When the shuttering for the two sidewalls was up, and the overhead struts on the springing line of the arch in position, there was only room for one wagon on the road. The plan adopted was to mix the concrete outside the south end of the tunnel and load it into wagons, from which it was then cast direct into the side walls: these latter being brought up alternately by three boards at a time.

It was found possible to keep this work of lining going pretty continuously; one gang was always at work either pulling down or erecting woodwork for the sheeting of the sidewalls or the centreing of the arch, another gang concreting sidewalls, and a third gang of bricklayers putting in the arch. These bricklayers, as well as the leading miners and drill men, had to be imported from Scotland, there being apparently no labour of this class to be got in the South of Ireland.

The chief difficulty all through was the arranging of access for men and materials owing to the small size of the tunnel, and this should undoubtedly be one of the points most carefully considered in estimating the time of completion, and incidentally the cost of a tunnel of small section. One would be apt to think that because one tunnel is only one-third the sectional area of another that it should therefore be driven at three times the speed, but in reality the difficulty of getting at the work, and the constant waste of men's time waiting for the road to be clear for their stuff to get in or out, make a small tunnel job much longer and more costly proportionately than a big one.

As regards the lining of tunnels the best materials should be used that can be afforded, as repairs are difficult, dangerous and costly when trains are running. If of brickwork, the facing should consist of brindles, which are both harder and less porous than any ordinary brick, and less brittle and liable to chip as well as cheaper than blues. Care should be taken that the work is properly bonded, and it is distinctly advisable to use nothing but cement

mortar, as this is not only stronger and more watertight than lime, but enables the centreing to be struck sooner and with less precaution. The parts where the bonding of the brickwork gives most trouble are the feet of the shafts, where the supervision of the work should be undertaken by a thoroughly competent inspector. This should also be the case with regard to the keying of the arch, especially where two lengths meet, and a " pigeonhole " has to be filled. This final piece of keying in has of course to be done from below, and the bond should be such that one brick only is required to be jammed in and wedged until the cement has set sufficiently to hold it in place.

A good description of all such details of work can be found in *Simm's Practical Tunnelling*, published originally in 1844, and in a monumental work of great interest and containing full accounts of various tunnels and systems with a magnificent collection of plates, sections, and diagrams by Henry S. Drinker, called *Tunnelling, Explosive Compounds and Rockdrills*, published by John Wiley & Sons, of 53 East 10th Street, New York, in 1893. As a specimen of a reference work on tunnels in general, with the exception of the new tubular method introduced by the late Mr. Greathead, and now so much in use in London, there is probably nothing to be found more complete than this admirable, but of course rather expensive volume. The actual details of different methods of timbering and construction which have at various times been adopted can be studied in this work to great advantage, and even though reference to it may not be actually necessary it will prove most interesting reading to all engineers from the tables of cost and description of machinery employed in various American works.

Information on the subject of tube railways not touched on in this paper may be found in the Proceedings Inst.C.E., Vol. CXXIII. *Greathead on the City and South London Railway*, and Vol. CXXX. *Hay and Fitzmaurice on the Blackwall Tunnel.*

INDICATING HIGH-SPEED STEAM ENGINES.*

By A. Marshall Arter, A.M.I.C.E.

[Read before the Society, on Thursday, January 8th, 1903].

The first part of this paper is devoted to descriptions of several indicators. In discussing the Watt indicator the following passage occurs. In the course of a conversation the author had with an engineer who had spent a considerable time in Russia. He said: "That about thirty years ago he was at the waterworks that supply water to the Suharel Tower, near Moscow, and there he saw an old beam engine made by Boulton and Watt, and as it appeared to be of rather ancient design and interested him, he examined it and found near the end of the beam what proved to be a movable cover, placed and made in such a way that its presence would not readily be perceived, unless the beam were to be carefully examined; after a little trouble this cover was removed, and in the recess that it concealed was found an indicator similar to the one just described." The engine had been working continuously since the year 1829, and the care with which this indicator was concealed shows that it must have been one of the very earliest sent abroad, and is characteristic of these earlier secretive methods.

The paper then turns to the use of indicators, and runs as follows:—It was found advisable, when indicating the new engines of torpedo boat destroyers, to increase the piston clearance, and also to vary it according to the cylinder; the indicators were accordingly numbered, in order that they might be easily distinguishable and used for the same cylinders—high, mean, or low-pressure.

Darke instruments were mostly used, and their pistons were eased to the following diameters:—

Piston of indicator for high-pressure cylinder to 0·795 in. diameter; piston of indicator for mean pressure to 0·796 in. diameter; piston of indicator for low-pressure to 0·797 in. diameter;

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their original diameters being 0·798 in., the high-pressure having the most clearance, as it had the greatest tendency to stick owing to the presence of grit. These clearances are not absolutely necessary when the engines have been in use for some time, but Professor Jacobas, after carrying out some experiments in America to compare the mean effective pressures of simultaneous cards from different indicators, says that: "A leaky piston is much more reliable than one that is too tight a fit; a piston which will not fall through the cylinder by its own weight may be too tight and produce errors due to friction." Often when the engines were quite new the above clearances did not suffice, burnt oil and Perkins metal sometimes finding their way into the indicator in such quantities that a diagram from one end of the cylinder only could be obtained, and often none at all.

In cases such as this it was found necessary to resort to a special indicator piston, the one shown in the sketch being applicable to Darke instruments; the length of the clearance in piston "A" being made greater than the total travel, so that the grit could lodge there while the card was being taken. The small surface also of this piston in contact with the cylinder, compared with the ordinary one, offered less area for the grit to work upon, thus reduces the friction, also greater facility for the steam to rush by, and so keep it clean. When these pistons are used it is advisable to drill two more holes in the top of the cylinder similar to the one already there to reduce the back pressure that might otherwise be considerable. This piston was not found necessary for the low-pressure cylinders, as low-pressure cards can always be obtained if the indicators are well blown through and cleaned. It was also found advisable with new engines to unscrew the cylinder cover, removing with it the piston and parallel motion, &c., and to blow the indicator well through from each end of the cylinder before taking each card. Specially substantial milling being provided on the edge of the cover to facilitate this was specified for when the indicators were ordered. No lubricant was used, the clearance round the piston allowing sufficient steam to blow past, keep it clean, and form the necessary film.

Springs are generally supplied in multiples of eight and ten, the multiples of eight being made to enable an ordinary rule to be used. The Crosby and Tabor indicators are both supplied with double helical springs; the lower end of the spring of the former has threaded upon and fixed to it a spherical steel bead by means of which the spring is fixed to the piston, and upon which all the piston pressure comes. This acting at the centre of the piston does not produce any bending moment and unnecessary friction between the side of the piston and cylinder such as an ordinary single helical spring fixed in the usual way, tends to do, the foot of the spring, which has the maximum motion, being thus very much lighter than is the case with the ordinary design. It is necessary when springs

are in constant use to test them at frequent intervals, either by comparison when under steam with a standard pressure gauge or by the deadweight principle, in which steam is used only to heat up the indicator before the weights are applied. Professor Carpenter has found that if springs are cold there is a mean error of above 3-6 per cent., and Mr. Brightmore $2\frac{1}{2}$ to 3 per cent., *i.e.*, if they have been adjusted hot, these errors are proportional to the pressures, and consequently the correction is a percentage to be added to or subtracted from the mean pressure found on the card. Most springs are adjusted at a temperature of 212° Fah., some a little higher. Professor Peabody, of United States, has found that whatever the steam pressure, providing the piston does not leak, that the temperature of the spring is nearly that due to the steam pressure, but that with a leaky piston, the spring being surrounded by steam at nearly atmospheric pressure, that the temperature of spring is approximately 212° Fah. These results were obtained by removing the piston-rod and inserting in its place a small thermometer, screwing the piston on to the spring and the spring into the cover as usual, hence the effect of steam leaking past the piston is to cool the spring and to keep it at the temperature at which it was adjusted, besides allowing a freer action.

The strength of an indicator spring depends on : (1) The maximum pressure in the cylinder. (2) The revolutions of the engine. (3) The number of expansions of the steam in the cylinder to be indicated. (4) The weight of the moving parts of the instrument.

The first condition requires the spring to be of sufficient stiffness to limit the height of the diagram. The revolutions and number of expansions govern the height of the diagram by keeping the average vertical speed at which the pencil travels within certain limits found by experience. The weight of the moving parts varies with different instruments, those having the lightest being able to give the biggest cards.

The makers of the Thompson indicator give a list of springs that they recommend for their two sizes of instruments, from which the following formulæ have been calculated for the large size, working up to 400 revolutions per minute :—The scale equals $0{\cdot}37 \times$ maximum pressure $+6$, and for the small size, working up to 600 revolutions per minute, the scale equals $0{\cdot}55 \times$ maximum pressure $+8$.

The makers of the Tabor instruments take the revolutions more into account, and recommend the use of the following springs :—

Revolutions.—Up to 200, scale of spring equals $0{\cdot}4 \times$ maximum pressure; 200-400, scale of spring equals $0{\cdot}5 \times$ maximum pressure ; 400-600, scale of spring equals $0{\cdot}67 \times$ maximum pressure.

The Crosby manufacturers say, "That the boiler pressure "expressed in pounds, divided by the desired height of the diagram, "will give the spring required," also "that the best diagram for

"measuring and interpreting is one in which the length is not more "than twice the height, for the reason that the points of cut-off, "exhaust and compression are better defined than in a longer one."

The author has found when using Darke indicators on torpedo boat destroyers that for varying pressures and constant revolutions of 400 per minute, the best height for a diagram is given by the expression :—

$$H = \frac{\text{maximum steam pressure lb. per square inch} + 240}{440}$$

Also for a constant pressure of 200 lb. per square inch, and varying revolutions, that $H = \frac{1200 - \text{revolutions}}{800}$. Associating these two formulæ we get an expression giving the maximum height of the card, taking into account both the steam pressure and the revolutions, and as the strength of the spring must vary directly with the steam pressure to give a constant height of diagram, we get :—

$$\text{Scale} = \frac{\text{maximum steam pressure lb. per sq. in.}}{\frac{\text{maximum steam pressure lb. per sq. in.} + 240}{440} \times \frac{1200 - \text{revs.}}{800}}$$

Of all the errors to which indicator diagrams are liable perhaps none is so often neglected as that which comes from the stretching and sagging of long driving cords. If on a base X Y, above, are plotted upwards ordinates representing the tension of the drum cord, produced by the spring X A being the initial and Y B being the final, the line A B will represent the increasing tension throughout the stroke. Similarly a line C D may be obtained by plotting, to the same scale, the inertia of the drum, which first acts in opposition to the cord and finally in conjunction with it, if the lines A B and C D are parallel, the spring is correct for the particular speed at which the inertia of the drum was taken, the tension of the cord, and consequently its length, being constant. Upon the speed being increased, the line C D assumes more the position of the dotted line E F ; increasing the tension of the drum spring only transposes the line A B higher up the diagram, such as G H, which still remains parallel to A B, and thus the effect of increasing the tension is only to reduce the relative—not the absolute—difference between the initial and final tensions of the cord. (See Minutes "Proceedings" Institution of Civil Engineers, vol. lxxxiii., page 74). Hence there is only one particular speed of engine for each drum spring at which the tension of the cord is constant. A means is therefore required of varying "the rate of increase of tension" of the drum spring, *i.e.*, its length, not its initial tension, but this is not so simple, and although fully recognised by the manufacturers, has not been embodied in any of the instruments ; there still remains, however, the alternative of

varying the weight of the drum, increasing its weight as the revolutions are decreased, by supplying with the indicators duplicate drum tops of various weights, having the revolutions stamped on them for which they are intended to make the maximum force due to inertia of the complete drums constant at those revolutions, by this means maintaining the inclination of the line C D constant at pre-determined increments of revolutions.

The Tabor Company sometimes supply separate drum springs for different revolutions, but more generally recommend that a shorter diagram should be taken as the speed is increased, viz.:—Revolutions × length equals 1000.

To register correctly an indicator must satisfy two conditions:—(1) The vertical motion of the pencil should be exactly proportioned to the change of steam pressure in an engine cylinder. (2) The motion of the drum must exactly be in proportion to that of the engine piston.

To satisfy the first condition, when the spring has been removed from the piston and all other parts replaced, if the indicator is in working order when the thumb is pressed against the steam inlet, the pencil should fall freely and slowly—the speed varying with the piston clearance—from the top to the bottom of its stroke, without any signs of sticking.

The following cards were all taken, with the exception of a few at the last, on torpedo boat destroyers, running at an average of 380 revolutions per minute and indicating between 5000 and 6000 indicated horse-power, according to class—27 or 30 knotters—and represent the faulty ones preserved for reference.

Notes on Defective Diagrams.

The oscillations in card No. 1, are in a great measure due to the whole indicator vibrating, the atmospheric line showing this very clearly. After the indicator pipes had been firmly stayed good cards were obtained. The admission lines of most low-pressure cards at these revolutions oscilate to a certain extent, giving a higher initial pressure than is actually the case, a comparatively light indicator spring being used; the sudden admission of steam causes the inertia of the indicator parts to raise the pencil higher than it would be if the steam alone influenced it; a reaction then setting in causes it to fall below the true position, and a series of vibrations result. Hence at these low pressures and comparatively high revolutions, the inertia of the indicator is beginning to make itself felt, as it did with the early instruments.

No 2 shows the result of pressing the pencil too hard and of having the indicator piston too good a fit, so that a little dirt, without actually causing it to stick fast, will produce a good deal of friction between the piston and barrel; the mean effective pressure was only 29·7 lb. instead of being nearly 45 lb., as it proved to be under more favourable conditions. Pencil friction is probably

proportional to the pressure, sharpness of point, material of the pencil, and surface of the paper; a smooth, fine-pointed pencil pressed with just sufficient force to make an extremely fine line was found the most satisfactory. The piston in this indicator had not been eased to gauge, as described, neither were the indicators blown through or cleaned out until they gave unmistakeable signs of sticking, the importance of which had not been fully realised until a later date.

The third diagram was taken from some new engines with an indicator in which the piston clearance did not allow sufficient steam to leak by and carry the grit away with it, or, perhaps, even there was not sufficient clearance to allow it to pass between the piston and barrel, resulting in a spasmodic action, producing lines in the form of steps that should have been curves.

No. 4 was taken with an old indicator, the joints in the parallel motion of which were well worn and allowed considerable play at the pencil, the effect of which was increased in the ratio of its travel to that of the piston, viz., four times. At the commencement of the admission lines the pencil rose higher than was warranted by the initial steam pressure. If the indicator had been in good working order a card similar to No. 5, in which the pencil fell almost as suddenly as it rose without enclosing practically any space, would have been the result, but the play in the joints allowed the piston to fall considerably before the motion was transmitted to the pencil; the drum meanwhile revolving, the pencil drew a line at some distance from that made when it rose, increasing falsely the area of the card. The difference in the admission lines of cards Nos. 5 and 6 shows the effect on the indicator of compression No. 5 having practically no compression; the steam being suddenly admitted, caused the pencil to rise too high; whilst in No. 6, there being a little compression, the pencil rose more gradually, and a truer card was obtained.

No. 7 is a good demonstration of the use of too light a spring for these revolutions; upon a stiffer one being used the projections at both ends of each diagram disappeared. The initial pressure was 180 lb. per square inch; revolutions, 400 per minute; and spring used was $\frac{1}{150}$; according to the formula it should have been the nearest one obtainable to $\frac{1}{185}$.

The diagrams on card No. 8 have travelled along the paper from left to right. The atmospheric line being taken first, is on the extreme left, each successive diagram being more to the right. This was caused by the string being new and untwisting immediately it was put in tension, increasing its length; but as this cannot go on for ever the obvious remedy is to allow the drums to rotate, when the string is new, for a few seconds before taking the card, or to use either a plaited cord or one having a flexible wire core.

No. 9 exhibits a similar defect to the preceding one, in a more aggravated form, but the cause was not the same. In this case the

string was exceptionally wet, and the holes in the adjusting piece were larger than they should have been, and considerably countersunk, with the result that the string was actually drawn through them, thus gradually increasing its working length.

No. 10 is an instance of the use of too long an indicator cord, allowing the drum to knock against the stops at the end of the stroke, the resulting rebound producing the indentation on the right of the diagrams. The right-hand diagram of No. 11 gives apparently a higher initial pressure than the other one, and no vacuum.

This is the result of the piston union slacking back during the interval that elapsed between taking the two diagrams. The pencil was thus raised by an amount equal to the distance that one card is above the other, a little less than two turns of the screw would do this; it shows the advisability of running over all parts liable to slack back before taking a diagram when there is the least vibration. The loop and abnormal shape of each diagram on the right-hand of No. 12 is the result of having a long driving cord without a guide to steady it. The adjusting piece, ring, and hook used should have been lighter than was the case. The inertia of the string and appendages produced a beat in the string, occurred when it was rising and nearing the end of its upward stroke, the drum spring being then at its least tension. When the point A of the lever—sketch A—to which the string was attached was in its highest position, the adjusting piece, &c., which can be represented by a weight "W," being unable to rise any more, it can be imagined followed the path of an arc, having A as centre, momentarily imparting a motion to the drum in the opposite direction to which it was travelling, the motion being reversed by the string straightening itself, as indicated by the dotted lines, before A descended sufficiently to counteract this excess travel, and imparted the true motion, in the opposite direction, and thus the peculiar formation was obtained. The loop was produced by a combination of this motion and the inertia of the indicator parts causing the pencil to rise too high—see cards Nos. 4 and 5—while the drums rotated in the opposite direction to which it should have travelled at that period of the stroke.

This beat does not necessarily run in step with the engine revolutions, varying with the length of the string and the weight upon it, and thus the irregularity of the drum travel does not produce a similar effect in all the cards taken with the same indicator and under the same conditions, a good illustration of which is afforded by the next two cards. Messrs. Schneider & Co., at the Paris Exposition, 1900, showed a marine engine in which the indicator was a considerable distance from its level, and to overcome these oscillations they fitted a second lever, pivoted to a boss on the cylinder near to the indicator, and connected to the reducing lever by a steel rod; by this means the cord to the indicator was not more than 15 in. long.

No. 13 and 14 were taken immediately after one another, and had a lead weight attached to the driving cord in order to see what the effect would be of a still heavier weight than the usual adjusting piece; it will be noticed that the right-hand end of the former has the peculiar formation due to the beat of the string, similarly to No. 12, whilst the latter is free from this, but exhibits more compression, particularly for the top-end card. The string can be imagined to have vibrated, and to be straightening itself at the commencement of the top-end, card No. 13 increasing the motion of the drum about the middle of the down stroke marked I, showing apparently a later cut-off and a higher pressure than was actually the case at that period of the stroke. Upon the maximum vertical travel of the string being completed, the energy of the string appendages resulted in the sharp rotation of the drum, first in the opposite direction to which it should have travelled—part II.—and then back again—part III.—producing the above formation as in No. 12. But in card No. 14 the effect of this vibration is seen later missing the extreme right of the top-end card, the string first straightening itself and commencing to vibrate outwards near the end of the return stroke, retarding the rotation of the drum for part I., and correspondingly increasing it for part II., thus registering a much earlier apparent compression and producing a thinner card, showing a lower mean effective pressure than was actually the case. The mean effective pressure for No. 13 is 42·8 lb., whilst that for No. 14 works out to 30·4 lb. This, of course, is an extreme case, but it demonstrates when indicating at high revolutions the necessity of keeping the weight of the string attachment as low as possible, and also, when the indicator is some considerable distance from the lever, of a guide for the string if accurate diagrams are to be obtained.

The next two cards show the necessity of this guide No. 15 being taken without one and No. 16 with one; all other conditions were the same; the engine was making 384 revolutions per minute, and they were both taken as soon as possible after one another, the adjusting piece, hook, &c., on the string were of the standard light pattern, but its length was unavoidably long. It should be noticed that the left-hand of the top diagram, No. 15, is distorted as well as the other, showing falsely an increased compression.

No. 17 was taken on a trial previous to that on which No. 12 was taken, and with a shorter driving cord than the latter had. The sticking at the end of the stroke was the result of grit and want of piston clearance. The loop was produced by a beat in the string coming at the opposite end of the card to any that had been considered up to the present, in Nos. 12 and 13 the beat occurred when the drum spring was at the least tension.

No. 14 came about mid-stroke, and now we have it still later more nearly at the end of the stroke. This beat—the string appendages not having been reduced in weight to the standard light

pattern—combined with the rise of the pencil, due to the inertia of the indicator parts and the sudden admission of steam, produced the loop, the card being elongated after the pencil had risen. When the point A of the lever—sketch B—was just commencing to rise, it is possible that the heavy adjusting piece, &c., on the spring vibrated from positions 1 to 2, and then the drum might either have remained momentarily stationary, or continued its motion if the inertia was sufficient, as it must have been in this case, instead of reversing it at the instant that the lever began to rise. Hence the horizontal positions of the diagram at this end of the stroke are behind their true positions, the drum actually travelling in the opposite direction to which it should have travelled, the vertical positions being, however, approximately correct. If this card had been examined without the conditions under which it was taken being inquired into, it is quite probable that it would have been accounted for by excessive compression and a leaky piston.

Drum Spring Experiments.

To further investigate the effect of oscillations on the motion of the drum, a drum spring testing apparatus, as ordinarily used to investigate the varying tensions of the driving cord, was arranged so that the reciprocating motion for the drum should be transmitted through it. The only difference between the experimental and the actual conditions of running was that in the latter case the string was inclined slightly from the vertical, and in the former it was horizontal, for convenience. The apparatus consists of a rod B—see sketch C—held in place by two bearings, which is reciprocated by means of a connecting-rod A working on a crank, a bell-cranked pencil lever C, to which is connected the indicator string at C^1, and a spring S, with two nuts D D^1 serving to rigidly fix one end, also to adjust the tension of the spring and the position of the diagram on the paper, which is pinned to a hinged board F. If the tension of the drum cord had been constant, the pencil P would have drawn a straight line, parallel to the centre line of the spindle B; when, however, it decreased the pencil rose, and *vice versâ*.

In all the diagrams the full lines represent the varying tensions of the driving cord, and the dotted ones the effect of the oscillations which were, in all cases, produced by attaching to the string about one-third of its length from the indicator a small lead weight, representing the weight of the adjusting pieces, &c., first used, all other conditions remaining the same, the two diagrams for comparison being taken immediately after one another. When the string is horizontal, as for the experiments, the oscillations run in step with the reciprocations, gravity acting at right angles to its motion, and thus all the cards showed this effect in the same manner; in this respect they differ from those taken with a nearly vertical cord. When taking these diagrams the effect of pencil

friction was very marked, it being possible by sufficient pressure to considerably alter their shape and size.

Diagram No. 18 was taken at 150 revolutions per minute with an indicator designed for high-speed work, say, 400 revolutions; the inclination of the diagram is due solely to the increasing tension of the drum spring, which at high revolutions should be counteracted by the inertia of the drum, producing a diagram similar to the above, but straight and horizontal. The right of the card is the commencement and the left the finish of the stroke, which is the case with all the four following diagrams; the lines being close to one another show that the relative tensions of the forward and backward travels of the string at any point of the stroke are practically similar, which at higher revolutions was not found to be the case.

No. 19 was taken with an indicator in ordinary working conditions with a volute drum spring at 300 revolutions per minute, and No. 20 with a helical spring 280 revolutions per minute. During the outward stroke of the first one shown by the arrow on bottom of full line a nearly constant tension is shown, and a considerable less tension during the return stroke. Upon the lead weight being put on the string, the oscillations set up and produced the new figures—shown dotted—the effect on the return stroke of No. 19 being to, at first, increase the rotation of the drum, string straightening itself—Fig. D—then to decrease it by commencing to oscillate at Fig. E. When the point O was reached the drum regained its normal position; but this oscillation, still continuing, continued to decrease the speed of rotation of the drum and prevented it from reaching the end of its normal travel—Fig. F—reducing the length of the stroke by an amount approximately equal to $\frac{1}{4}$ H multiplied by the ratio of the springs, which equals 0·1 in., or a reduction of 4 per cent. in the length of the diagram.

No. 20—helical spring—shows a more nearly constant tension during the return stroke; the oscillations producing irregularities in rotation more evenly distributed between each end of the stroke, whilst the total length of travel was not so seriously impaired. It is interesting to note that with the same weight and practically the same revolutions the cord oscillated considerably more when the first card was taken than the second, and it is probable when a driving cord is in constant tension that there is not such an incentive to oscillate as when the tension is variable.

Nos. 21 and 22 were taken just after the apparatus was completed and before a lighter pencil arm was substituted for the original one, which was too heavy. They can, however, be compared with each other, as they were both taken under the same conditions, but must not be compared with any of the others. The first one was taken at 300 revolutions per minute, with the indicator as it is ordinarily used, and being such an open diagram it suggested that the inertia of the drum was too great for the spring.

The portable part of the drum, containing part of a roll of paper, was therefore taken off, and then even at 400 revolutions per minute a much smaller diagram was obtained, showing that the weight of the drum was too great for the spring at these revolutions. The last four diagrams have been selected from a number, and represent the average results obtained.

When Nos. 19 and 21 were taken the drum contained little more than half a roll of paper, which may be taken as the average working conditions, and its effect is not negligible. The necessity of having the string in the same plane as the lever moves in, and at right angles to its mid-position, if the travel of the drum is to accurately represent on a reduced scale the travel of the engine piston, is well demonstrated by card No. 23, the left end of which is extended whilst the other is compressed. It was taken with the indicator in position 1, sketch G, it being impossible to place it in its correct position 2, on account of its inaccessibility, the result being that the stroke was not equally divided when reduced and transmitted to the indicator, as shown by the three positions of the string and of the lever. This was rectified by the lever being bell-cranked, as sketch H, by means of which a correct relative motion was imparted to the drum. Similarly, if the indicator is in its correct position relatively to the short end of the lever, whilst the long end of the lever by some means or other is not at right angles to the centre line of the cylinder at mid-stroke, an unequal relative motion will be transmitted to the indicator, which, if the fulcrum is in position 1, below its true position 2, sketch J will be the reverse to that resulting from an arrangement similar to the sketch G.

No. 24 is an example of the combined effects of the two preceding ones, namely, string vibration, No. 17; bad lead, No. 23. It is obvious that instead of bell-cranking the lever a similar result may be obtained by guiding the string for a short distance over a pulley placed so that the string from the lever is at right angles and in the same plane with the lever when it is in its mid-position.

No. 25 also suffers from the indicator being incorrectly placed, as No. 23; the extension coming on the right instead of the left may be accounted for by the use of a different type of instrument, in which the drum is rotated in the opposite direction; also by reason of the indicator being fitted with too weak a spring the vibrations on the steam lines appear.

No. 26 was taken from the low-pressure cylinder of an engine running at 200 revolutions per minute that had not been indicated for some considerable time, and points to an obstruction in the pipes; when the indicator was blown through preparatory to taking the diagram, the amount of steam that came from the top end of the cylinder was much in excess of that which came from the bottom, the latter just coming out with a sort of hiss, and containing a lot of water. It will be noticed that the effect of wire-

drawing here is to increase the back pressure and reduce the initial, there being very little flow of steam through the indicator; the larger the volume to be filled between the indicator and the obstruction the greater this latter effect will be. The author when experimenting found that, with a very small hole close to the indicator, while the initial pressure was considerably reduced, the small volume of steam enclosed soon escaped past the obstruction and that the back pressure was only slightly increased.

No. 27 was taken after the pipes had been cleaned, and still shows a small card for the bottom end, which was caused by water in the pipe; in fact, there was so much present that it was almost impossible to blow steam free from it through the indicator.

No. 28 was the best card obtainable, blowing well through between each diagram. The effect of too long a drum spring is demonstrated by No. 29, which are two sample cards taken from series of 34, 16 of which were taken at 500 revolutions and give a mean length of 2·1 in.—see diagram shown dotted—whilst the remaining 18, being taken at 400 revolutions, have a mean length of 2 in.—diagrams shown full. In other words, the diagrams taken at 500 revolutions are 5 per cent. longer than those taken at 400 revolutions. The cords from the levers were vertical, and being designed to give a length of 2 in., could not have increased it this 5 per cent. except by oscillations, which was not the case, as the cords were guided; when the indicator used the left-hand of the card was the part drawn when the drum was wound up against the action of the spring. At 400 revolutions the tension of the spring at the end of the outward stroke was sufficient to overcome the inertia of the drum, but at 500 revolutions it was not strong enough, the inertia of the drum carrying it past the end of its normal travel, allowing the string to sag. This elongation occurring practically only at the end of the stroke, when the diagrams through compression and expansion were very thin, has the effect of reducing the mean effective pressure of the card. The M.E.P. of the one shown in full lines taken at 400 revolutions is 50·8 lb.; that for the 500 revolutions one shown dotted is 51·8 lb., which may be accounted for by the slower one being smaller at the bottom end than the other. On the 500 revolution card being shortened to its proper length, *i.e.*, 2 in., the curves being traced by hand approximately similar to the 400 revolutions, one at the top end only, an M.E.P. of 53·5 lb. was obtained, showing that the drum spring in this case is responsible for a 3 per cent. reduction. With high revolutions and very light spring, slight pencil friction has the effect of improving the card, giving the varying pressures in their true occurrence and eliminating the effects of inertia, as will be seen on examination of the friction diagram No. 30, which was taken with $\frac{1}{2}\frac{1}{4}$ spring at 500 revolutions per minute; during the succession of quick oscillations the pencil moved so rapidly over the

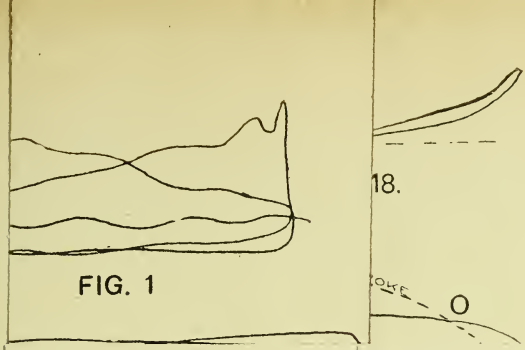
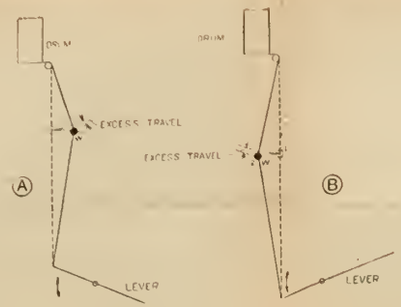
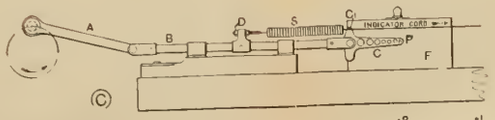
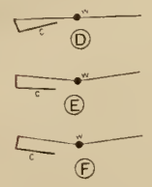
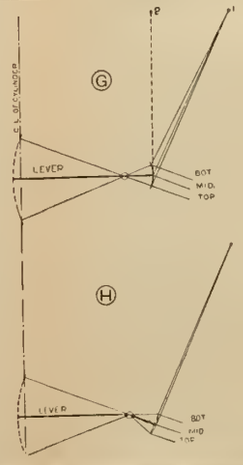


FIG. 1









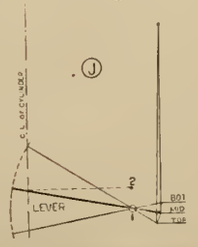


FIG. 1

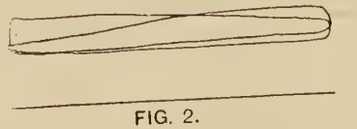
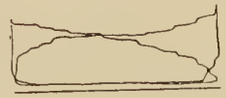


FIG. 2.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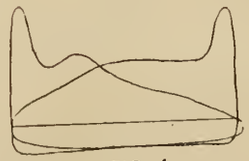
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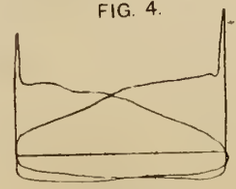


FIG. 5.

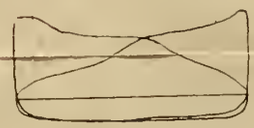


FIG. 6

FIG. 7.

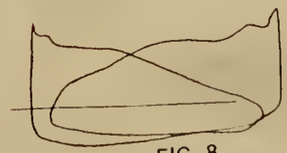


FIG. 8.

FIG 9.

FIG. 10.

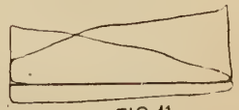
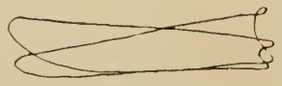


FIG. 11.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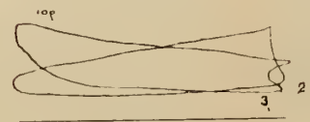


FIG. 13.

FIG. 14.

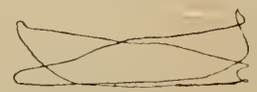


FIG. 15

FIG. 16.

FIG. 17.

FIG. 18.

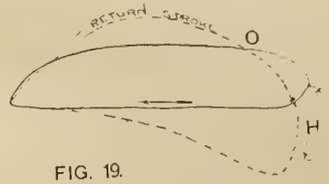


FIG. 19.

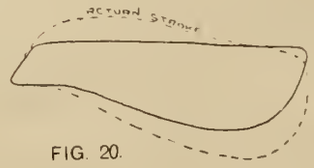


FIG. 20.

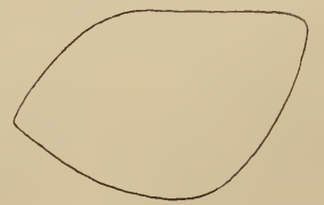


FIG. 21

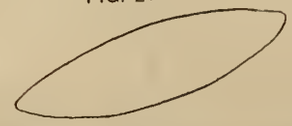


FIG. 22.

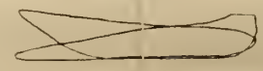


FIG. 23

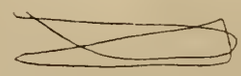


FIG. 24.

FIG. 25.

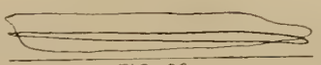


FIG. 26.

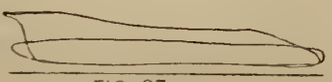


FIG. 27

FIG. 28

FIG. 29.

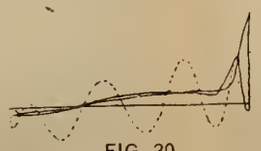


FIG. 30.

FIG. 31.

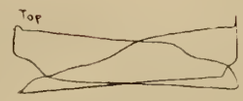


FIG. 32.

FIG. 33.

FIG. 34.

paper that it drew a number of dots, which were just visible, instead of a continuous curve.

Drum friction is the cause of the peculiar formation of card No. 31. Immediately it was removed, all other conditions being similar, No. 32 was obtained. It was produced by the small nut on the top of the drum—which in all probability had the wrong cover on. The nut should have been screwed hard down to a shoulder on the spindle and then just cleared the cover, its function being to stop any vertical movement of the drum. On the outward stroke the drum was forcibly rotated by the string against this friction to the end of its travel, but on the return stroke the spring was the only force available, and, not being sufficient to overcome the friction, did not rotate the drum at its proper relative speed or produce a diagram of the correct length.

To try the effect of still further increased drum friction, the nut was screwed hard down, and then a diagram taken ; No. 33 was the result. It will be noticed that the diagrams are on the left of the card towards the end of the outward stroke, when the drum spring was at its maximum tension, and that the spring was only partially able to re-rotate the drum, as shown by the atmospheric line below, which was drawn before the nut was screwed down. On the nut being slackened back, No. 34 was obtained. The difference between Nos. 32 and 34 is due to linking up, and does not affect the experiment.

In conclusion, the author would point out that he has endeavoured to investigate the cause of the defects produced in diagrams by the indicator and its gear, not those due to defective steam distribution, which have been many times exhaustively treated. Too much importance cannot be attached to having the working parts of the indicator free, to frequent blowing through, and to good leads, free from sagging. The comparison of cards Nos. 21, 22, and 29 shows the importance of being able to vary the weight of the drum as suggested. Mr. Seaton—*Marine Engineering*, page 27—says :—

"That in whatever way the mean pressure is measured, it forms the "basis of calculation of actual energy, and is therefore of the utmost "importance, since most modern formulæ bearing upon marine "machinery and propulsion are based upon the indicated horse-power. "Any error in taking the diagrams must lead to errors in design by "calculations from formulæ based on false premises. This should "always be borne in mind by the operator, on whose skill and care "a good and true diagram depends as much as on a good "instrument."

SOME RECENT WATER TURBINE PLANTS.

By A. Steiger, M.Inst.C.E.

[Read before the Society on February 5th, 1903].

Water power has lately received much attention in all countries, owing to the rapid development of electricity and its application to the most varied purposes. In view of the fact that we can by means of electricity transmit power to almost any distance, and that we can make use of the electric current for a great variety of purposes, such as lighting, heating, cooking, and industrially for supplying energy to factories and for chemical and metallurgical processes, &c., it is not predicting too much to say that it will soon pass from the stage of luxury or a mere commodity to that of a necessity. Already we see numerous villages in Switzerland provided with electric generating stations, using the current in private houses for all possible purposes, and even in peasants' huts.

To make the commodity of electricity available for all, it is necessary to produce it at a low cost, and to do this a cheap source of energy is required. In Great Britain there is a general belief that because coal is—or was once—cheap, artificial power is cheap. This belief may account for the sources of water power of this country (up to the present time) being rather neglected, or not considered worthy of attention. Mr. Hawkshaw, the president of the Institution of Civil Engineers, in his address, stated that coal has about doubled in price during the last 15 years, and with this fact before us it may be useful to direct attention to the sources of water power in this country.

It has been the privilege of the author to read a number of papers on this subject, as he is intimately acquainted with the utilisation of water power of all kinds, having installed a number of turbines under all possible conditions. The most attractive manner of treating an otherwise dry subject is that of describing existing plants with some characteristic features in them, and the author proposes to follow this course. Before doing so he would like to draw attention to the enormous change which had taken place in water power installations since the advent of electricity.

Twenty years ago it was considered a great achievement to produce a turbine which would give, say, 600 b.h.p., and this would have required a high fall; now, the engineer whose task it is to design turbines and power installations is given the task of concentrating a large amount of power in as few units as possible, whatever the fall may be. The 5,000 h.p. turbines erected 10 years ago at the celebrated Niagara Falls, with a head of 140 ft., are being superseded by the new ones, which are now being put in of 5,500 b.h.p. each, and these again are dwarfed by the 10,000 b.h.p. turbines to be erected on the Canadian side of the same falls. Still more gigantic is a scheme now in hand to erect turbines of 1,400 b.h.p. under a fall of 10 ft. Each of these units, if put under the same fall as at Niagara, would give off 74,000 b.h.p.

More modest, but certainly not less interesting, are the many small and moderate falls in these Islands, with a very short water supply in the dry summer months, and an abundance in winter, or after continued rain. Certainly the irregularities of the water supply, which sometimes affect the fall also, are a great drawback to using such sources of energy, but to say they are useless is absurd. If only constant waterfalls were useful, then we should have no water-power installations in Switzerland.

We shall now see how such falls can be most satisfactorily utilised. The first occasion on which the author had to deal with such a varying waterfall in this country was when Cossey Mills, near Norwich, was converted to the new roller system. The water supply of the river Wensum, on which the mill is situated, varies between 4,200 cubic feet per minute, in the very driest weather, and more than 10,000 cubic feet per minute in flood time. The fall as well as the amount of the water supply varies, so that the highest fall of 6 ft. 3 in. corresponds with the minimum supply, and the minimum fall at ordinary flood times of 3 ft. 10 in. corresponds with a supply of 10,000 cubic feet or more. The minimum supply not being sufficient to produce the necessary power, the turbine had to be supplemented by a steam engine, and the author decided to adopt a turbine which would give the highest possible efficiency, with the minimum supply, but at the same time to make it large enough to produce the full power required, *i.e.* 50 b.h.p. under the minimum fall of 3 ft. 10 in. Thus the use of steam power would be reduced to a minimum.

The type which would fulfil this condition in the best manner was the double-crowned Jonval turbine. These are axial flow pressure turbines, which require the buckets to be entirely filled by the water passing through them. In order to obtain a good efficiency, with a reduced water supply, these wheels are divided into two or more compartments, so that the outer one is just large enough to pass the minimum quantity of water under the full head, while the inner one can be opened according to requirement when the fall is reduced. The outer compartment, having a mean diameter of 9 ft., is used

with the higher fall when the velocities of the water and that of rotation is greatest, while the mean diameter of the turbine when fully opened for use, under the minimum fall, is only 7 ft. 6 in. Thus the subdivision of parallel flow turbines into several compartments of different diameters enables us, besides securing a good efficiency with a diminished water supply, to obtain also a constant speed under a varying fall. At Cossey Mills the turbine runs at a constant speed of 27 revolutions per minute, whether the fall is 6 ft. 3 in. or 3 ft. 10 in.

Although the efficiency of pressure turbines generally is much less affected by the so-called critical speed, the advantage of a carefully-designed parallel flow turbine, with several compartments is, in many cases, of greater importance than the possibly somewhat higher efficiency of certain radial flow turbines, especially where the variations of the fall are great. This type (Fig. 1) has been extensively used on the Continent under similar conditions, and the author has had equal success with low falls in this country down to 24 in.

We find this type used also in electric generating plants, for instance at Baden, Aarburg, and Interlaken in Switzerland, but since then the necessity for a quick-acting governor became more and more apparent, and although not impossible, it would require a somewhat complicated arrangement to fit it to parallel flow turbines. "Necessity is the mother of invention," says a proverb, and some of the Swiss turbine builders designed a new hydraulic governor to take the place of the old mechanical governors. At the same time they applied such improvements to radial flow turbines as would render them highly efficient at "part gate." This is a *conditio sine qua non* in sources of water power having varying conditions of fall and water supply. These two inventions constitute a great progress in hydraulic power installations, due mostly to the modern requirements of plants for generating electricity.

No better example of the progress of the times, as regards hydraulic power generation, could be given than the complete transformation of the once-celebrated installation at Schaffhausen, in Switzerland. There, nearly 40 years ago, three Jonval turbines were erected on the left bank of the Rhine, each capable of producing about 250 b.h.p. under a fall varying between 11 ft. 6 in. and 14 ft. 9 in. This power was transmitted across the river to the town side by means of two wrought-iron wire ropes of 1 in. diameter running at a velocity of 62 ft. per second, the distance being 390 ft. There the direction was changed by means of bevel wheels, and the power carried along the right bank for about half a mile, portions being given off to the various factories at each intermediate station. All this has now disappeared. New turbines of increased power have been put in in place of two of the old ones, each driving a dynamo, and the power is transmitted electrically to the different factories.

The new turbines of the inward flow type are constructed to give 350 b.h.p. instead of 250, and owing to the impossibility of altering the turbine chambers, their diameter, namely, 6 ft. 7 in., had to be chosen to suit the locality, and they run at a speed of 60 revolutions per minute. They are regulated by means of a register gate connected with a hydraulic governor. The old turbine floor having been placed at a considerable height above the lowest tail-water level, the new turbines are provided with conical suction tubes reaching below that level. Properly constructed suction pipes are of great value, as they permit of a turbine being placed at a considerable height above tail-water level, and also of increasing the efficiency of the turbine by reducing the amount of unutilised energy. The power generated by the turbines is transmitted to a horizontal countershaft, by means of bevel wheels, and the dynamos are coupled direct to the countershafts, which run at a speed of 200 revolutions per minute. This seems rather slow for a generator of 260 kw., but space had to be considered, and the existing building could not be enlarged to any considerable extent.

Among similar turbines which have been erected in this country may be mentioned the installation of two turbines of 50 b.h.p. each (see Fig 2) at a corn mill in Sligo on a tidal river. The problem of the utilisation of a tidal river, with the fall varying from 8 ft. 6 in. to 6 ft. 6 in. at neap tide and 3 ft. at spring tide, was rather fascinating. The new wheels have been placed exactly where the old ones stood, and connected to the line shaft, the position of which was given. It was therefore impossible to put in an absolutely ideal new installation, which would have given a constant supply of energy down to about a 4 ft. fall. The neap tide level was taken as the highest tail-water level, allowing a minimum fall of 6 ft. As the fall is gradually reduced by the rising, and increased by the falling tides, the admission of water must be varied correspondingly, in order to maintain the power constant, and it is desirable that the efficiency should remain a good one at all gate openings.

The gate described in connection with the Schaffhausen turbines is most satisfactory from this point of view, if the water is very pure, but may be a source of great trouble where the water carries with it sand, weeds, and such substances. The turbines at Sligo are regulated in a different but equally effective manner. The guide blades are made movable on pins, and by giving a turn to the regulator spindle the passages in the guide wheel are simultaneously opened or closed on the whole circumference. This system of regulating turbines is old, and used in many inward flow turbines, but in almost all of them the efficiency falls off very considerably at half gate, and less than half gate. All pressure turbines require a continuity of flow in order to give a good efficiency, and by regulating turbines in the aforesaid manner we disturb that continuity,

and it required some ingenuity to design turbines which would allow such a disturbance without loss of efficiency within a wide range of gate openings. Very often the success of a turbine installation depends entirely on a good constant part gate efficiency, which, however, we shall hardly ever be able to obtain from pressure turbines as we do from impulse wheels.

Impulse turbines are in the first instance suitable for high falls, with relatively small water supply, but there are instances of low falls where the use of an impulse turbine is imperative from the point of view of economy. The author was once asked to supply a turbine (see Fig. 3) for a fall varying from 11 ft. to 12 ft., with a water supply of 2,000 cubic feet in winter time, dwindling down to 430 cubic feet in summer, and to guarantee a good efficiency for that reduced supply of nearly one-fifth of the maximum. No other than an impulse turbine would have answered this requirement. But ordinary impulse turbines must run clear of the tail water, otherwise their efficiency is bad. Yet it would be wasteful to place the wheel under the fall of 11 ft., and thus lose 1 ft. or nearly 10 per cent. of the total head, especially considering the largely diminished water supply. In order to use the full head and let the turbines run temporarily in the tail water without much loss of efficiency, the wheel vanes have been so constructed that without abandoning the impulse principle the water fills them entirely in passing through. The tail water will thus not interfere with the normal flow of the water and reduce the efficiency. Impulse turbines are, however, very sensitive as regards the best speed, and if the fall had varied more it would have been very difficult, if not impossible, to obtain such good all-round results.

Probably the best known power plant in the whole world is that at Niagara Falls. Here again we can obtain a distinct and rapid progress in the design of turbines for special cases. The first installation put down—scarcely 10 years ago—consists of six turbines of 5,000 b.h.p. each. They are all outward flow turbines of the Fourneyron type, and the water is divided between two wheels on one common shaft. These turbines are regulated by a mechanical governor. The speed is 250 revolutions per minute, and the generators are coupled direct to the top of the vertical turbine shaft. The new series of 11 turbines which are now being erected in the new power-house are 10 per cent. larger in power, and are of the more efficient inward flow type. They are placed about 22 ft. above tail-water level, but the full fall is utilised by the aid of suction pipes.

One of these new turbines is illustrated in Fig. 4. The turbine wheel, 5 ft. 3 in. diameter, is cast entirely of manganese bronze and weighs 36 cwts. It is contained in a cast-iron casing made in halves, into which the water is taken by pipes, 7 ft. 6 in. diameter, and the draught tube is arranged in the shape of a fork which serves as a support for the casing on which the guide wheel is fixed. The

turbine wheel is placed about 40 in. above the bottom of the casing, to allow stones, &c., which may be carried into it, to settle and be removed from time to time through a separate outlet, while floating bodies are retained at the top of the casing. Thus no damage can come to the wheels.

The gate by which these turbines are regulated is an annular ring of bronze moving between turbine and guide wheel parallel to the axis. It closes by its own weight and that of the levers and and rods by means of which it is connected with the governor, which amounts to about 12 tons. The weight is balanced by the hydraulic pressure exerted on the piston of the governor, which may be increased to 24 tons. The governors are the invention of Messrs. Escher, Wyss, & Co., who also prepared the designs from which these turbines were made in America. These governors form not the least interesting part of the whole installation. They will be referred to later on.

The turbine shaft reaches to the top of the pit and is about 120 ft. long, carrying at its top the pole wheel of the generator. The weight of the turbine with its shaft and the revolving part of the dynamos amounts to about 71 tons. This great weight is very nearly balanced by a column of water of the height of the fall, acting on the lower side of a piston of 53 in. diameter, fitting nearly, but not quite, tight into the cylindrical part of the draught tube, just underneath the turbine casing.

The footstep is placed in the upper gallery, just below the machine floor, and is of the modern type, with annular rings submerged in oil, which constantly circulates between the contact surfaces, and is kept cool by a pipe through which a constant flow of water is maintained.

The new turbines, of 10,000 b.h.p. each, to be erected on the Canadian side of the falls, by the same firm, are of the same type, and the arrangement is similar, but two wheels will be fixed on one shaft, and the weight of the machinery balanced accordingly.

The satisfactory governing of turbines in an electric generating station is very interesting, but also a very difficult problem. We can regulate the largest steam engine with the greatest ease and accuracy by a pendulum governor acting on a valve, but the gate of a turbine is too heavy to be moved by the direct action of this pendulum, and the latter can only serve to introduce some outside force which will act on the regulating gate when required. This outside force may be either power from the turbine itself or hydraulic pressure. Ingenious as many of the mechanical combinations of the governing arrangement are, they are all much too slow for electrical work, and do not prevent over regulation. By substituting liquid pressure we obtain, at once, a rapid motion of the regulating mechanism, and "hunting" is almost entirely overcome.

Hydraulic governors consist generally of a pendulum, a steering

valve, a servo motor, and the mechanical connection with the gate of the turbine. The steering valve is moved by the least change of speed, and then admits or excludes water under pressure to the piston of the servo motor, the movement of which is transmitted to the gate. At the same time the movement of the piston returns the valve to its normal position, cutting off the hydraulic pressure, and stopping all further motion of the piston until a fresh change of speed takes place.

The natural pressure of the water may be used in connection with such governors, with falls of 40 ft. or more. If the fall is smaller, a pump is used to produce the necessary pressure, and in that case oil takes the place of the water. At the Niagara Falls the governors are placed in the machine room above the head water level. Artificial pressure was therefore necessary, and this substitution of oil was adopted.

Remarkable results have been obtained from one of these governors connected with one of the old turbines, as will be seen from the diagram Fig 5. Whether the load is suddenly increased or reduced, or entirely thrown off, in no case does the speed vary more than 3½ per cent., and with a gradual change of load the maximum variation of speed amounted to only 2 per cent. The normal speed was re-established in about half a minute after each change, and no "hunting" could be observed. The diagram at the bottom shows a comparison of the action of the old mechanical governors on five turbines with that of the hydraulic governor connected with the sixth turbine, running in parallel with the others, the hydraulic governor regulating the whole 30,000 b.h.p.

In this country we have one large power plant at Foyers (the power being used for the manufacture of aluminium and carbide of calcium) consisting of seven turbines of 700 h.p. each under a fall of 350 ft. These are Girard turbines running at 140 revolutions per minute to suit the speed of the dynamos. The largest water-power plant in the British Dominions is that at Cauvery Falls, in India, which was successfully started last summer. This installation, which is shown in Fig. 6, supplies power to the Kolar goldfields, 93 miles distant from the Falls. A fall of 400 ft. has been obtained by building a dam and cutting a canal about three miles long to a cliff near the Falls, where the intake was built, with three separate chambers for three pipe lines, and a settling tank for water, used exclusively for the hydraulic governors. Each pipe line supplies two generator turbines, each having a maximum output of 1,250 b.h.p. These are, however, only taxed up to 1,000 b.h.p. under normal conditions. Besides these there are two turbines of 144 b.h.p. each for driving the exciters.*

* N.B.—This plant is now being enlarged by the addition of five new generator turbines of 1,250 b.h.p. each, and one exciter turbine of 144 b.h.p., making a total of over 14,000 b.h.p.

Both the generators and the exciters are coupled direct to the shafts of the turbines. These are a special design of Pelton wheels, with two inlets or nozzles. The generator turbines have a diameter of 5 ft., and run at 300 revolutions per minute, and those for the exciters 40 in. diameter, and run at 470 revolutions a minute. The power of the turbine is regulated by reducing or increasing the area of the nozzles, and each turbine is regulated entirely independently of the others. It is obvious that the hydraulic governors must be of the highest standard to enable the generators to run in parallel. The principle of the governors is exactly the same as described before, but the pressure of the water itself is used to act in the servo motor. A special filter, which can be cleaned without stopping work, is attached to each turbine to admit only pure water to the rather delicate regulating valve. It was guaranteed that with sudden variations of load of 10 per cent. the normal speed of the turbines should be kept constant within 2 per cent., with a sudden variation of load of 25 per cent., within 4 per cent., and with a sudden variation of load of 50 per cent. within 8 per cent. Tests which have been made show that when the whole load was suddenly thrown off the speed of the turbines rose a little more than expected; but even with that severe test the no-load speed (which is about 5 per cent. above the full load speed) was established within about half a minute.

Such governors were tested at an electric power station in Switzerland, and the results recorded automatically by a tachograph. These results are shown by the diagram Fig. 7. The higher curve represents the speed variation which could reasonably be hoped for when the whole load of 500 b.h.p. was suddenly removed. The actual variation is represented by the lower curve. The maximum increase in speed at no-load of 7 per cent. was reached $4\frac{1}{2}$ seconds after throwing off the load; then the speed goes down again $4\frac{1}{2}$ per cent. in another $4\frac{1}{2}$ seconds, to rise once more to $2\frac{1}{2}$ per cent., and the normal no-load speed, which is 4 per cent. higher than the full-load speed, is reached, and maintained constant after about 20 seconds. Probably a steam engine governor would not show better results than these.

The sudden action of hydraulic governors is naturally felt in the penstock, and becomes very dangerous to the pipe line under a heavy pressure. In order to prevent the pipes from bursting under the severe shocks produced by the rapid closing of the nozzles, a special release valve is connected with the governor, which opens simultaneously as the nozzle is closed, and allows the water to escape to the tailrace. This valve, immediately it has been opened, begins to close again automatically, but so gradually that the pressure in the pipe line cannot increase more than about 5 per cent. The author saw, at a turbine installation in Switzerland, that if one of two units of 800 b.h.p., each running under a head of 935 ft., was thrown off suddenly, the

pressure in the pipe line did not increase more than 3 per cent. When hydraulic governors were first applied it was thought necessary, as a precaution against bursting the pipes, to connect large air vessels with the pipe lines, but it was soon found that the arrangement just described was absolutely reliable, and any further precaution unnecessary. The deflecting nozzle, often used in connection with Pelton wheels, have the same purpose. They are simpler, but of course the water is wasted.

Sometimes it is necessary to create a new type of turbine, with a view to obtaining certain advantages. It has been mentioned before that it is desirable to concentrate a large power in a few units and yet obtain a comparatively high speed. Such a new type has been introduced by Escher, Wyss & Co., and has been adopted, among other installations, for the generating station which supplies Lyons with light and power. Fig. 8 represents one of the eight turbines of 1,250 b.h.p. each, driving the generators direct at 120 revolutions per minute. The fall varies from 33 ft. to 40 ft., but may sometimes be reduced to 26 ft. The wheels are cone shaped and divided into three compartments, each of which is regulated independently, by means of annular gates moving upwards and downwards. The top compartment is only used when floods reduce the fall to a minimum. This type combines the advantages of the parallel flow turbines with that of the greater speed and better efficiency obtained from radial flow wheels, and is, therefore, particularly suitable for low falls on large rivers. The turbines are enclosed in a casing, to which the water is conducted in pipes 8ft. 3in. in diameter. The cover of the casing is provided with a cylindrical part of 6 ft. diameter, into which fits a piston keyed on to the turbine shaft. The pressure due to the fall, applied to this piston, balances the weight of the revolving parts. In the same plant eight turbines of 1,500 b.h.p. each have also been erected. These run at 120 revolutions per minute, but in order to obtain that speed for these more powerful wheels the water had to be divided between two inward flow wheels fixed on the same shaft.

There are numerous electrical generating stations in which the dynamos are coupled direct to the vertical shaft of the turbines. This arrangement is extremely convenient, and saves much space, and, very frequently, also expense for foundations and buildings. A saving in power is also effected by balancing the weight on the footstep, and reducing the friction in same to almost nil. The habit of using existing patterns of dynamos and perhaps some conservatism seems to stand in the way of a more general adoption of the vertical arrangement. On the other hand, the arrangement with a horizontal shaft has many great advantages ; especially does it simplify the transmission of power to line shafts by mechanical means. We frequently find, therefore, turbines fixed on horizontal shafts even under low falls.

Fig. 9 represents a turbine giving 250 b.h.p., which is now being installed under a fall of 13 ft., and intended to drive a dynamo. With such a fall it is impossible to obtain a speed sufficiently great for the turbine to be connected direct with the dynamo. Even by dividing the water between two wheels a speed of only 95 revolutions per minute could be obtained. The power is transmitted to the dynamo, which runs at 270 revolutions per minute, by means of plaited manilla ropes. The turbine is placed in an open water chamber, and the water passes from the wheels to the tailrace through a flume and suction tube.

A small but none the less interesting turbine plant is that at Lynmouth Electricity Works. A turbine was installed there about 14 years ago to drive direct two Mordey alternators of 37½ kw. each, at a speed of 650 revolutions per minute, utilising a fall of 94 ft. With the increased demand for current and the short water supply in dry weather it was found necessary to replace the old wheel by a more economical one, which is shown in Fig. 10. It develops 95 b.h.p. at full gate. The characteristic feature in this particular turbine is that the whole efficiency is almost constant at 81½ per cent. between half gate and three-quarter gate; it falls so slightly with a smaller gate opening that at 0·225 gate opening it amounts still to 70 per cent. It is often the case with inward flow turbines that the efficiency at full gate is somewhat smaller than at, say three-quarter gate. This is due to the tendency of obtaining a higher speed than is justified for a given fall. It would have been better to adopt a speed of, say, 500 instead of 650 revolutions per minute in the first instance, when, no doubt, the full gate efficiency would have been as good as at three-quarter gate.

These few examples of modern turbine plants show that we have to deal with a great variety of conditions. Almost every one of them has some peculiarity of its own, which requires special consideration and independent treatment. If one type of turbine has given good results in one case it may be most unsuitable in another, even if the fall is about the same. It is a great hindrance to the proper development of water power to treat all cases alike, and eventually to look upon turbines as an ordinary article which can be manufactured and put on the market wholesale, using sometimes high-sounding names as a bait to buyers.

One word should be added with special reference to the sources of water power in this country. A mere superficial investigation will show that if properly utilised they will be most valuable. Of course, the high falls, which are easier and less costly to utilise, are only found in Wales, Scotland, and Ireland, and the mountainous parts of England, and they will be made use of in the first instance. But the low falls which we find in all flat parts of the country, should not be overlooked.

Wherever an undershot or low breast wheel is found, with head and tail race existing, the cost of replacing these wheels with suitable turbines, and thereby increasing the power, sometimes doubling

and nearly trebling it, is not very great. The very existence of a water wheel shows that power is needed at that spot, and if fuel had to be brought to replace it the power from it would be very expensive.

If the capital outlay for a good turbine plant, with the interest on it and cost of maintenance during, say, 20 years, is put against the same expenditure for a steam plant of the same capacity, adding in the latter case the outlay for coal and labour, it will be found that much more money has been spent for the steam plant than for the water power plant, even if the capital outlay for the latter may have been double that of the steam plant. These low fall powers are generally small, and there can be no question that it would be too expensive to transmit them to any considerable distance; but if used locally, and if due regard is taken of what may reasonably be expected from them, with an efficient turbine these small powers will be found very useful. Water passes down the rivers day and night, and if we can apply the power to one purpose during day time and another during night time, we are enabled to produce power so cheaply as to be available in every house.

The irregularity of the water supply is a great objection to the use of some sources of water power, and it is impossible to entirely overcome this difficulty, but something could be done to minimise it, apart from the use of turbines with a good part gate efficiency. Considerable damage is often done by floods in the low-lying countries, but the water which causes these floods is not that which falls on that part of the country; it is the water which gathers on the top of the hills and rushes down to form one large stream. If we build dams to retain part of this water in the hills we can prevent the floods, at least to some extent, and use the water thus stored for irrigation in the dry season or for power. Large irrigation works are erected in India, Egypt, and other countries where irrigation is indispensable for the cultivation and prosperity of the country; similar works would render invaluable services in an industrial country, by securing a more regular flow of water for power purposes.

The value of regulating the water supply in this manner has long been recognised on the Continent. So long as half a century ago Napoleon III. suggested, after some destructive floods in the Loire Valley, the erecting of dams and reservoirs in the hilly parts of France as a preventative to similar disasters. The work was carried out for the benefit of the flat parts of the country, effectively preventing damages by floods, but now, as the demand for cheap power is increasing, these reservoirs are found of great value for that purpose. A movement to regulate the water supply in this manner and for the same purposes is now going on in Germany, and other countries on the Continent, and it is to be hoped that this country will not remain behind in making the best possible use of its water powers.

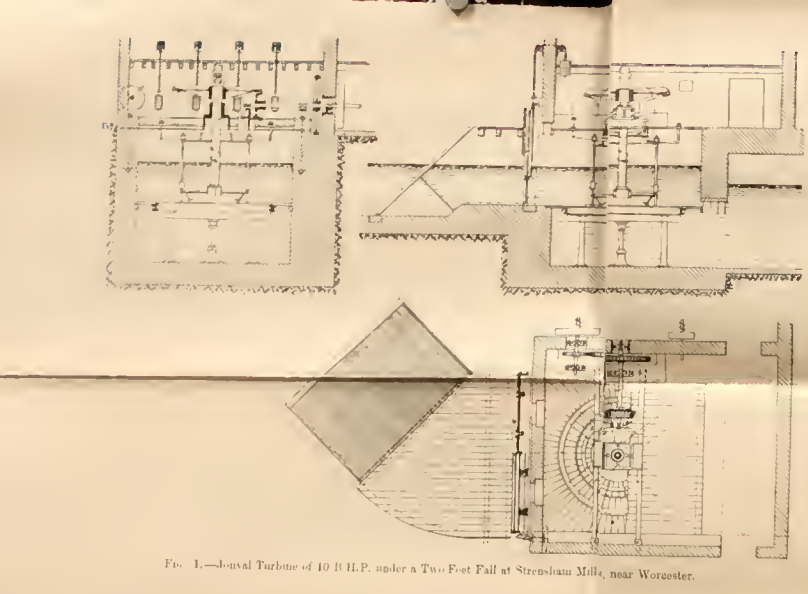


Fig. 1.—Jonval Turbine of 10 H.P. under a Two Feet Fall at Strensham Mills, near Worcester.

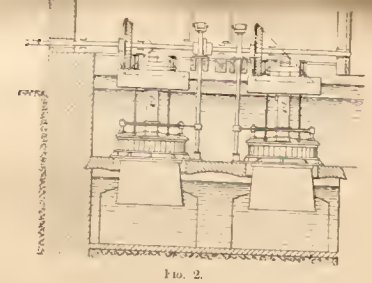


Fig. 2.

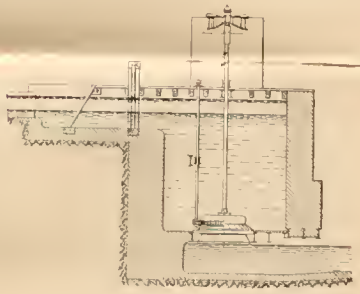


Fig. 3.

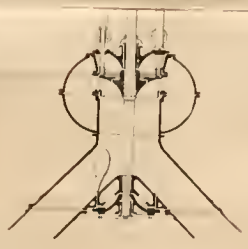


Fig. 4

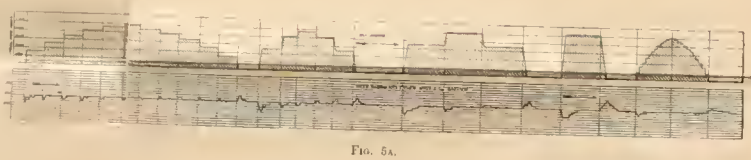


Fig. 5A.

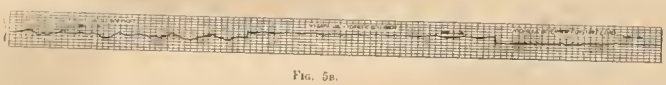


Fig. 5B.

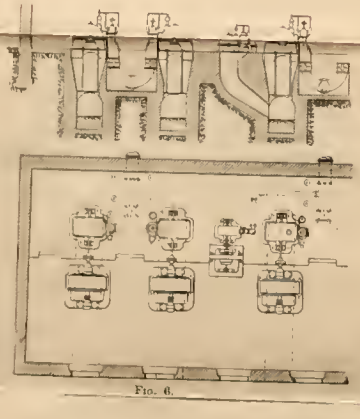
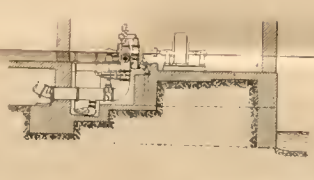


Fig. 6.



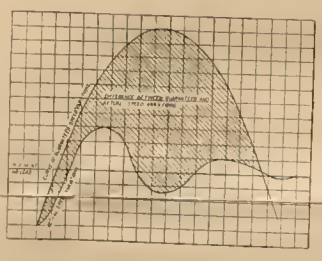


Fig. 7.

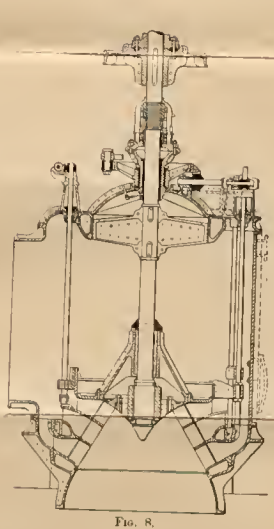


Fig. 8.

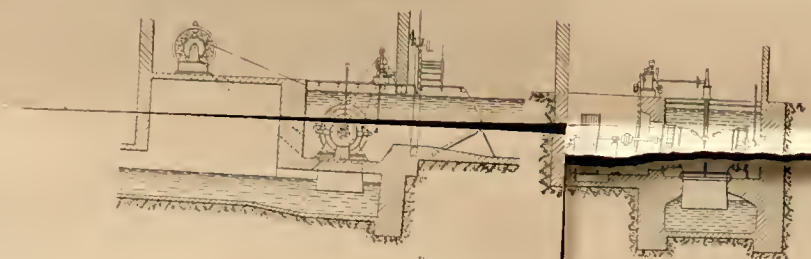


Fig. 9.

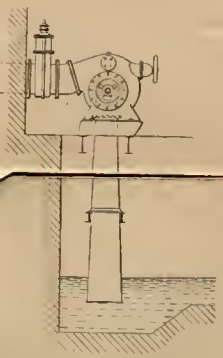


Fig. 10.

THE PRODUCTION OF POWER BY MEANS OF GAS PRODUCERS AND ENGINES.

By Robert W. A. Brewer, A.M.I.C.E., A.M.I.M.E.

[Read before the Society on March 5th, 1903].

The author divided his remarks into two classes: First, a general idea of the principles involved and the advantages and economy to be obtained, for the benefit of those who have only recently considered the subject; secondly, a few important details, for the successful working of a plant depends on the design and construction of details.

In this country we are solely dependent upon our coal supply for the production of large power, and experts are continually bringing to our notice the fact that our coal supply is limited. The question now is, "How to make the most of what we have remaining?"

Unfortunately there are very many engineers and shipbuilders who do not yet appreciate and acknowledge the vast economy that is effected by the adoption of gasified coal. Whether this form of fuel be adopted for firing boilers, or for direct combustion in the cylinders of engines, the resulting economy is most marked. When coal is burnt on a grate flame is produced from the gases which are distilled from the coal by the heat below it burning with the surrounding air. There is, too, the glowing fuel in the lower part of the fire, consuming away without flame. When the fire is thick, and contains only glowing fuel, short blueish flames rise from the surface.

In burning coal directly in the boiler there are continued variations in the temperature of the furnace, which cause gases of different calorific value to be given off from time to time. These variations are at the root of the smoke nuisance in our large towns, and are also a considerable source of loss to the consumer. If we could keep the temperature fairly constant, and regulate exactly the quantity of air required, we could produce much more satisfactory results.

Advantages of a Producer.

Gas should be made from the coal in a separate enclosed producer, and carried by pipes to the place where it is required for combustion.

For firing boilers the gas needs no purification, and small bituminous coal is the fuel used, no smoke being given off. There is, of course, a sooty deposit in the gas flues which require cleaning out from time to time. The air for consumption with the gas is brought in flues round the boiler setting, and is thus heated before admission to the furnace. The quantity of air and gas can be accurately adjusted before entering the grate, where complete combustion occurs. The analyses of gases made in various producers are as follows, in per cent. by volume:—With steam jet blast, generally used,

CO, 23·4 ; H, 13·8 ; CH_4, 2·25 ; CO_2, 4·7 ; N, 55·85 ;

fuel used, fine slack. Working a producer with an excess of steam for the recovery of ammonia, the analysis would be approximately,

CO, 11 ; H, 28 ; CH_4, 2·5 ; CO_2, 15·5 ; N, 43 ;

the first three being combustible gases, and the last two inert.

Gas produced with an excess of steam will require cooling and scrubbing to a certain extent, before being used under a boiler, in order to remove the undecomposed steam.

The amount of heat in the original fuel, which is used to transform it into gas, is about 10 to 13 per cent. ; but this is not strictly a loss due only to the producer, as when the fuel is burnt in the boiler heat is also required to gasify the green fuel and raise its temperature. Multitubular boilers are particularly adapted to gas firing, as the heat due to combustion is distributed throughout ; but when directly fired by coal only a portion of the tubes is useful as heating surface. The absence of ash, too, is important, also the risk of cracking tube plates, due to a sudden fall in temperature, as when the fire doors are open is removed.

The Producer to Use.

There are a variety of producers on the market ; each has some special feature. For many years anthracite producers have been used, and have done excellent work at a low cost, the consumption of fuel being under 1 lb. of coal per horse power hour with gas engines.

These producers are very convenient for small powers, but the cost of anthracite rather excludes their use on a large scale. The gas given off is clean and uniform, and is usually generated by means of a superheated steam blast inducing the necessary amount of air. Gas can be made at intervals of about 20 minutes, or continuously, an attachment to the gas holder regulating the supply of steam to suit the load. This gas is used to a large extent for direct combustion in engine cylinders, and by means of coke and sawdust scrubbers is rendered quite clean enough for that purpose. The importance of a good producer and its attachment is, however, most manifest when dealing with bituminous slack.

One of the chief causes of trouble has been the amount of tar in

the gas. The type of grate to employ for satisfactory continuous working has received much attention in order to obtain complete gasification of all the fuel, with a minimum of ash and clinker. In the old types of producer, with closed grates, there was the difficulty of cleaning and the stoppage of working for that process.

Air should be admitted to the centre of the glowing fuel, and permeate in all directions, upwards and sideways, so that there is no green fuel in the vicinity of the grate. If the blast is simply forced outwards to the walls of the producer, clinker is formed where the air impinges, and there is a mass of fuel out of the direct action of the blast. Flat grates have been tried, but these must be freed mechanically from ash by revolving, and there is a risk of good fuel falling through with the ash. A grate or grid which overcomes these difficulties is made A-shaped, and runs across the inside of the producer, having its legs resting on the bottom of a water seal. The whole apparatus is built over this seal, which slopes up to the floor level at the two sides. The fuel properly rests on a mass of ash standing in the water seal. The surface of the ash is level with the perforated part of the grid, which is slotted on the two sides of the apex. This grid forms the air distributer, and is supplied at the end with the blast. Air and steam rise through the centre of the fuel, and outwards to the sides. There is thus no portion out of the direct line of blast, with a result that perfect gasification occurs, owing to the large grate area and perfect distribution. As the working continues ash is drawn from the water seal, allowing the fuel to sink, fresh coal being fed at the top. With the largest size of grate about one ton of coal per hour can be dealt with. This type of grate is most successful when used in connection with ammonia recovery.

As before stated, gas for firing boilers is not usually cleaned; but for use in engine cylinders scrubbing and cooling is essential. As the hot gas, at a temperature of about 500° Cen., leaves the producer it passes through a regenerator, heating the incoming blast. The blast is further heated by passing down an annular casing round the inner shell of the producer. The gases are passed through one or two rotary washers, fans being usually employed, and at the centre of these a water supply enters. This water is dashed about, and cools the gas to about 90° Cen., at the same time precipitating tar, which is drawn off. The gas passes upwards through a cooling tower, where it meets a downward stream of water, which water can afterwards be used for heating the blast. Sawdust scrubbers are also necessary, which require cleaning out periodically, as any tar still remaining is deposited here. The gas then is led to a holder and to the mains. The calorific value of producer gas is about 140 thermal units per cubic foot, but varies slightly under different conditions of working. The efficiency of any method of converting heat into work is one of the main points to be studied.

A Mond plant of 1,000 horse power will produce at full load 72 cubic feet of gas of a calorific value of 146 thermal units cubic foot from 1 lb. of slack, whose calorific value is 12,200 B.T.U. per pound ; while at one-third load the production will be about 71 cubic feet, of a calorific value of 144·5 thermal units cubic foot. The efficiency of the plant is thus about 86 per cent. when ignoring the heat introduced in the form of steam, but including this the efficiency will come out at about 70 per cent. The comparative cost of fuel for steam engine and gas engine with Mond producer and dynamo driving will be about : Cost of fuel per Board of Trade unit, Mond gas, 0·15 penny ; cost of fuel per Board of Trade unit, steam engine, 0·22 to 0·3 penny.

It will be noted that the gas plant is to the gas engine what the boiler is to the steam engine, and it is even more important to consider the former than the latter, as the gas produced is subject to greater variation in quality than is the steam in pressure.

It is important that the gas be uniform in quality, and suitably chemically constituted for the work it has to perform, and that these conditions can be maintained for several consecutive hours. Producers should be able to work economically at light as well as full load.

The fact of several generators being worked together does not effect the quality of the gas if the arrangement is suitable, there being many installations of a battery of gas producers in this country.

When large quantities of steam are carried through a generator it often is a sign that the fire is not dense enough or deep enough for the quantity of steam used. The depth of the fire depends on the size of the generator and nature of the fuel.

Some producers have an arrangement to define the active depth of the fuel. A funnel descends from the top of the producer, the green fuel being fed into this funnel. Thus the active depth is the distance from the grate to the base of the funnel, the gas rising from the surface of the fuel around the base of this funnel.

With bituminous coal hydrocarbons are given off when the fresh fuel is put into the generator. It will thus be seen that an automatic feed is desirable for large bituminous producers.

Dowson gives figures regarding the efficiency of his plant, which varies from 79 to 82 per cent. With a heat efficiency of 80 per cent. the losses may be accounted for as follows :—

	Per cent.
Loss in boiler	7
Steam not decomposed	1
Fuel lost with ashes	2
Sensible heat of gas lost in cooling, etc., and radiation	10
Total ...	20

The efficiency of the Mond plant, calculated to the same basis as the above, is 79 per cent.

Blast-furnace Gas.

A blast furnace is an ideal gas producer. The enormous volume of gas produced in blast furnaces is now being turned to useful account in many cases, though at present a most inefficient method is practised, in which about 40 per cent. is burnt under boilers, the remainder being either wasted or used for heating the air blast. A rough analysis of this gas is given per cent. by volume—

CO, 27·5 ; H, 1·5 ; CO_2, 6·0 ; N, 65.

The composition of these gases varies with the working of the furnace, but when used on a large scale both the variations of composition and pressure are negligable. When used under boilers these gases depend on the CO they contain for their heating value, and about 400 cubic feet are consumed per horse power hour. In a gas engine the consumption is about one-fourth of this, with an equal volume of air. It is on account of the high compression used that we have this high thermal efficiency. At the pressure obtained there is no difficulty in igniting the charge electrically.

A similar method of purification and cooling has to be carried out to that for producer gas ; but owing to the dust contained in furnace gas a more elaborate scheme of precipitation and washing has to be employed. Two fans in series have been found satisfactory for removing the lighter dust, the heavier particles being arrested in a series of pipes and towers. It is advisable to have a gas holder of moderate capacity, but not essential, the enormous volume of gas produced and used makes it impracticable to store an appreciable supply.

Several large engines have been built and are now running on blast-furnace gas, the majority of these engines being made abroad. Entire satisfaction has been given in their working, and no doubt the many thousands of horse power now wasted in this country will before long be to a great extent utilised for the production of electricity for lighting or electro-chemical industries. Of all the fuel consumed in a blast furnace only about one-half is at present used, and it is the remainder that we want to turn to good account.

Large Gas Engines.

Continental and American makers are much ahead of us in the manufacture of large gas engines. Not only do they make larger cylinders, but also have a variety of types. The two-cycle engine is coming into favour for large powers, as the weight per horse power and the diameter of the cylinder are kept within smaller limits.

The Oechelhauser has at present been constructed solely for use with blast-furnace gas, and consists of one long cylinder, with two pistons moving in opposite directions. The engine is of the two-cycle type, an air pump and a mixture pump being attached. When the pistons are in their outward positions, the exhaust port

being uncovered at one end by a piston, a blast of air drives out the remaining products of combustion, and any accumulation of dust. The admission of the mixture of air and gas, which immediately follows, must be accurately timed, so that the piston, which acts as an exhaust valve, has returned over the ports. Objections have been raised to the principle of this engine, on the grounds of the possibility of gas being driven right through the cylinder. Even if this does take place to a small extent, the volume of gas dealt with is so enormous that a small waste in this direction is immaterial. It is unlikely, too, that the escaping gas will fire in the exhaust pipe, as it would be too poor to do so when mixed with products of combustion and not compressed. Any small defect such as this would be amply compensated for by the proportional weight of the engine per horse power as compared with the other types on the Otto cycle. It will be noticed that in this engine there is no regular exhaust valve to come in contact with hot gases. This valve is one of the chief sources of trouble in other engines, besides taking a considerable amount of power to lift it when not balanced. Owing to there being an impulse every revolution the weight of the flywheel can be kept down. There is about 13,000 horse power supplied by these engines at present, which have a thermal efficiency of about 30 per cent. per indicated horse power.

The double-acting engine of Körting, with a solid piston, compares very favourably with the single-acting types. One test of these engines gave the following results :—

I.H.P. motor cylinder = 544 Absorbed by pumps = 63	= 481 effective 1 H.P.
Brake H.P.	= 341 at 101 revs. min.
Mechanical efficiency ...	= 71 per cent.
Gas consumption ...	51 cubic feet per 1 H.P. hour. 81·5 cubic feet per B.H.P. hour.

Calorific value of gas 129 thermal units cubic feet (lower).

Compression 187 lb. per square inch absolute.

The Simplex engine, by Cockerill, has attracted a good deal of attention. This being an Otto engine has consequently a large cylinder for the power developed, and the space occupied is considerable.

Makers of gas engines are apparently following the lines of steam-engine makers, in that large horizontal engines are first put on the market, no doubt to be followed to a greater extent by those of a vertical pattern. The advantages of a vertical steam engine are so apparent, that it is to be wondered why large gas engines are not almost entirely made vertical. There are, as is usual in such a

case, several practical difficulties to be overcome, but English makers seem dilatory in the matter.

There is no reason why vertical engines should not be built with, say, three or four large diameter cylinders and a short stroke. Suitable cooling arrangements could be provided for the piston heads, and the ratio of wall area to cylinder volume kept down. By this means we should have a great temperature at the centre of the burning mixture and less radiation to the walls, with consequent increase in the thermal efficiency.

It has been shown by experiment that the temperature of the burning mixture, even only a fraction of an inch away from the walls, is considerably higher than that at a point on their level. As we know that about 25 to 40 per cent. of all the heat is lost by radiation, the less we can make the ratio of wall surface to compression volume the better will be the result obtained.

With this theory in view gas-engine makers have designed the compression space as nearly spherical as practicable, but recently we find the American practice in large vertical engines is to make the cylinder ends flat. Up to the present every satisfaction has been given by this arrangement, which also admits of the valves being placed on the cylinder covers, a distinct advantage, and which facilitates a higher compression. However, experiment also proves that if the heat lost by radiation is reduced, that wasted in the exhaust is increased, which shows that some method should be adopted whereby we obtain more complete expansion of the gas, and thus reduce the temperature of the exhaust. This end can be reached by two methods, either by throttling the incoming mixture, or by keeping the admission valve open during part of the compression stroke, thus returning part of charge to a chamber provided, and using it next cycle.

Although the Otto hit-and-miss system of adjusting the gas supply to suit the load is so extensively used and so thoroughly satisfactory, as far as economical results are concerned, there are a few defects in this method of governing. In the first place, there is no means of adjusting automatically, the mean pressure in the cylinder, and consequently the power and speed undergo extreme fluctuations, which are only kept within reasonable limits by extremely heavy flywheels. Running at a quarter load the governor has to decide in one stroke out of eight whether the load has been increased or not, and if the former the power is at once doubled. There is, therefore, no adjustment within the limits of 100 per cent. If the load increase has been momentary, the engine will at once race.

In order to remedy this state of affairs the hit-and-miss arrangement has been abandoned by some makers, and a system of adjusting the quantity of mixture admitted for each charge has been adopted. This adjustment of the mixture allows the burning gases to expand to a volume which is greater than their volume at

atmospheric pressure before compression takes place. The result of this expansion is a lower temperature of the exhaust and a greater thermal efficiency at all loads except the maximum. It has been stated from time to time that such an arrangement of throttling in the limit or running light causes miss-fires and explosions in the exhaust pipe, etc. When the point of ignition is fixed sluggish firing does inevitably take place, owing to the reduced compression of the charge. With graduated impulses at constantly recurring intervals of four strokes, and with two strokes out of the four in which to decide the power in the impulses, it is only a matter of the means employed to obtain the successful result in the engine.

The system adopted by the Westinghouse Company throttles the charge during the whole of the suction stroke, and in so doing secures the graduated impulse, but loses the work done in the throttling, and has a further loss in that no provision is made for altering the time of ignition.

Apart from this, the method of governing these engines is admirable. The air and gas are controlled by cocks with graduated pointers, which enables the man in charge to determine exactly the best ratio of air to use to the gas supplied. When the engine is running on a steady load, if one mixing valve lever is moved while the other remains stationary the regulating valve stem will move up or down as the mixture becomes more or less efficient, indicating that a greater or less quantity is being used. If the gas cock is set, on gradually opening the air valve, the regulator valve will move down until the critical mixture is reached, when it will reverse its direction. Thus the correct mixture is a matter of exact measurement, and not of individual approximation.

The best system of governing large engines for driving dynamos and alternators, direct coupled, is undoubtedly Dunlop's variable expansion gear, which keeps the admission valve open during the whole of the charging stroke, and closes it at different points on the compression stroke, making no loss, and having two and a half strokes for control. This variation in the period of closing the admission valve results in a variable ultimate compression, and consequently for any given proportion of gas and air necessitates for economical working a variable point of ignition. The timing takes place earlier with lower compression, and thus sluggish firing is avoided, the heat being added at constant volume and maximum compression. The accompanying figure shows a simple piece of mechanism which produces these results, the necessary movement being supplied by an ordinary fly-ball governor of steam-engine proportions, acting through a link.

Fixed on the side shaft for operating the valves is an eccentric, having a cam-shaped strap. The upper part is formed concentric with the strap, and will at all times come in contact with the roller fo the admission valve at a constant point of the revolution, namely,

at the commencement of the charging stroke. At the point shown the roller has dropped off this portion of the strap, and the valve is consequently closed. It will be seen that by moving the strap round the eccentric the point of valve closure can be altered some little in either direction. The part of the strap under the roller is struck off from a point eccentric to the centre of the sheave. This part operates the ignition gear by means of the roller shown, and any motion which affects the closing of the admission will also adjust the time of ignition to suit.

This type of gear will be of immense advantage in the use of blast-furnace or producer gases, as the automatic variation in the period of ignition will at all times ensure the best working conditions within the cylinder.

Whilst discussing valve gear a few remarks on the exhaust valve will be appropriate. In the accompanying figure it will be noticed that by means of a sleeve fitted with packing rings the greater part of the area of the valve is balanced so far as pressure is concerned. This ensures that very little power will be required for the operation of the valve, which is a combination of a piston and mitre-seated type. The construction is novel, in that the stem is fixed on the upper side of the valve instead of the lower, which latter method is almost universally adopted in gas-engine practice. Further, the valve is made hollow from end to end, and communicates at its lower extremity with the exhaust passage. The object of this is the cooling of the valve by the circulating water passing from the jacket, which is essential in large gas engines.

The large quantity of heat rejected in the exhaust, even with expansion gear, is sufficient to heat the valve to redness and cause pre-ignition if proper cooling arrangements are not adopted. In addition to cooling the valve, the water on entering the exhaust pipe will so cool down the exhaust products that the noise will be much more effectually quietened than by the use of the gravel-filled silencers now adopted, and that without putting back pressure on the piston.

The advantage of having a free exhaust passage with no obstructing spindle is obvious, and the casting of the whole valve is very simple. No special shaft or gear is necessary for the operation of the exhaust valve, which is driven off the usual side shaft by means of a bell-crank lever and horizontal rod. Nor are there any special cam shifting gears and two-step cams required for starting. All that is necessary to obtain half compression is to prop the governor to its higher plane of running.

A method of discharging water in the exhaust pipe is carried out in the Westinghouse engine, with perfect results as regards quiet running.

Scavenging.

In the author's opinion too much stress cannot be laid upon the importance of a good positive scavenger. The whole secret of

success in a large engine is the effective cooling of the inside walls of the cylinder, in order to allow the maximum weight of explosive mixture to be drawn in at each charge. Also practice shows that large engines, which run on producer or blast-furnace gas, require the products of the previous explosion to be effectually cleared out of the cylinder. In addition to cooling the cylinder walls at the end of the exhaust stroke we have the compression space filled with air instead of burnt gas. Assuming this space is 20 per cent. of the total maximum volume of expansion, we can admit that percentage of increase in the gas supplied per charge and the power generated will be also increased. Also comparing indicator diagrams, those taken after a missed explosion on the Otto cycle are greater than those following a previous explosion, thus showing the effect of burnt gas in the cylinder. Positive scavenging increases the thermal efficiency about 5 per cent., and the Premier Company have obtained a mean pressure of 120 lb. per square inch with Mond Gas and water-cooled piston.

There are two distinct methods of scavenging in actual use—positive and induced. If the engine is driving a blower the addition of a valve and gear is about all that is required to make a very good positive scavenger, the action and effect of which is certain. Otherwise the addition of a pumping cylinder is necessary, either driven off the shaft, or an extension of the engine piston itself, working in a cylinder of larger diameter than the main cylinder. The annular space then forms the working volume of the pumping cylinder. For large vertical engines a good arrangement would be to provide a small cylinder with a piston driven from some reciprocating part of the engine. This piston would act as a cushion, and produce a retarding force on the reciprocating parts, tending to avoid reversal of pressure on the crank-pin brasses. Some of the air thus compressed can be liberated at the correct moment, and drive out the products at the end of the exhaust stroke.

The effect of positive scavenging on the pressure is most marked, as in two engines, with approximately the same ratio of compression space to working volume :—

	Maximum pressure.	Mean Pressure.	Compression.
Scavenger	325 lb.	108 lb.	120 lb.
Non-scavenger ..	240 lb.	51·5 lb.	73 lb.

Ignition.

The ignition of the mixture is carried out in various ways—the hot tube seems the general practice in England, and electric gear elsewhere. Undoubtedly electric ignition will become universal for

large engines working with poor gas, as it is much more certain in its action. Also difficulties arise with bunsen burners for tube ignition if coal gas is not obtainable, owing to the varying pressure of the gas, and the tar deposits on the adjusting needle and timing spindle. It is sometimes convenient to have both tube and electric ignition, as the sparking points of the igniter may become fouled; but ignition gear should always be in duplicate. The igniter used by the chief American firms embodies some excellent features, and consists of a removable plug fitting in a hole in the cylinder head, secured by two bolts to a projecting flange. This flange carries the binding posts for attaching the wire, and the mechanism for making and breaking contact. These posts and contacts are in duplicate, only one set being used at a time. In case of accident the second set can be switched into gear. The current is furnished by a battery or small dynamo, and through an induction coal and three-way switch; the current can thus be reversed at any time. The object of reversing is to transfer the minute particles, which follow the direction of the current on breaking circuit, from one sparking point to the other, and back again. By periodically reversing the current, the lasting qualities of the igniter are thereby augmented.

In the Fairbanks Morse (Otto cycle) engine there is a supplementary contact, which is operated by the push rod, for working the exhaust valves. When an idle stroke takes place no contact is made, and consequently there is no sparking. The contact in the usual way completes the return of the current to the sparking coil and battery. The sparking points, which are made of platinum to insure long life, are connected—one with the plug and body of the engine, the other to a rod working in two lava insulators. This rod has a steel die, which a moving knife edge pushes forward to bring the sparking points together. At any period of the revolution, which can be altered at will when the engine is running, this knife edge slips past the die and releases it; a spring immediately returns the moving contact to its original position, thus breaking the circuit. No tapping action takes place, only a gentle forward motion when making, and a click at release when breaking.

Starters.

The Fairbanks Morse engine has another notable feature with regard to its ignition gear, and that is a detonator worked by hand for starting. This detonator is screwed into the side of the compression space, and is made to hold an ordinary wood match. On pressing a knob sharply the match ignites, and fires the first charge of explosive mixture, which is pumped into the cylinder by a small hand pump which is attached to the side of the engine sub-base. The crank is first brought to its inner dead centre on the firing stroke, and a mixture of gas and air, or spirit vapour and air, is compressed in the combustion chamber. The detonator is fired

simultaneously with a slight forward impulse given to the fly-wheel by hand. This is a most satisfactory and simple starter. The use of petrol for starting large engines is much to be recommended. The starter takes up very little room as compared with compressed-air cylinders, and is always ready for use.

An increased pressure is obtained in the Lanchester starter, owing to the fact that the expansion of the burning gas in the receiver compresses the explosive mixture in the combustion chamber to a higher point than is usually obtained with other starters which depend on a hand pump for their compression. Also the work done in pumping up is less, as no compression is entailed, the air or exhaust valve on the engine being wedged open during the process. There is rather an uncertainty of the mixture striking, however, in a Lanchester starter when using poor gas, owing to the variation in quality, and for this reason an ordinary vapour pump is preferable.

Engines Generally.

There is a certain amount of similarity about the general design of gas engines built in this country. The trunk piston is universal, and is specially adapted to this class of work, owing to its facilities for radiation, which are assisted by the pulsation of the air set up by the reciprocating piston. The excessive heating of large piston heads has led some makers to avoid very large diameters and high compressions, in order to keep to the old designs. Seeing that so much progress is being made in large engines abroad, large pistons are made with water-cooled heads. In many cases this water cooling is fraught with some difficulty on account of the small space available for the necessary gear. The most practical and simple device for water cooling consists of an arrangement of two small plungers screwed into bosses on the piston at the extremities of a diameter. These plungers are hollow, and work in small diameter pump barrels fixed to the main framing or bed of the engine, which latter must be suitably designed to allow clearance for the crank webs. One plunger provides inlet water and the other the outlet, suitable valve chests being attached to the pump barrels.

One objection makers have to vertical gas engines is the difficulty of designing them to be easy of access to the piston and main brasses. There are vertical types of steam engines made with enclosed crank chambers fitted with doors, which can be easily removed, and allow a very fair amount of room for working. This arrangement can be quite well carried out with gas engines, as is shown by the Westinghouse engine. A notable feature of this engine is the method of taking up wear on the main bearings, which are supported in castings forming the ends of the crank case. The adjustment is made from the underside by means of wedges and draw bolts, two to each wedge forming a locking gear, and there are two wedges to each brass. As the wear on the main brasses is

always downwards, this method of adjustment restores the shaft to its original distance from the base of the engine. This is a particularly valuable feature in an engine direct-coupled to a dynamo, as the alignment of the shaft is preserved. Another point is that the clearance between the pistons and cylinder heads is maintained at a constant volume, and the degree of compression is unchanged. The adjustment of the brasses can easily be made, as no stripping has to be done, there being no liners in the brasses to be filed. The top brass is held in position by two set screws, which prevent it from moving round the shaft.

There is really no necessity to place gas-engine main brasses at an angle at all, as the wear invariably takes place vertically downwards, and adjustment can only be made perfectly with horizontally-divided brasses. It is thus the best practice to construct horizontal engine beds on the girder principle, having solid pedestals to carry the weight of the crank shaft and flywheel. The brasses can then be fitted in horizontally divided, and the lugs of the pedestals firmly bound together with tension caps. By this means we do not have bending stresses in the castings, the metal being equally divided on either side of the centre line. With this question of the direction of wear in view, the Fairbanks-Morse Company make all their engines with horizontally-divided brasses, the bed plate being suitably designed to take the stresses. These engines are also fitted with two flywheels.

Connecting rods in gas engines are submitted to sudden heavy loads in compression, the magnitude of which is often not fully recognised. Suppose, for example, the compression amounts to 100 lb. per square inch, and at the moment of firing the pressure rises to 350 lb. per square inch, there is a sudden load of 250 lb. per square inch, which, in the usual way, we equate to a dead load of 500 lb. per square inch. The load in compression is then 600 lb. per square inch of piston area, and the rod is practically a free-ended strut. Assume a piston diameter of 10 in., and the connecting rod 48 in. long.

By Unwin's formula the diameter of this rod $= d$.

$$d = 0{\cdot}038 \sqrt{\{Dl\sqrt{p}\}}$$

$$= 0{\cdot}038\sqrt{10 \times 48 \times 18{\cdot}75} = 3{\cdot}6 \text{ in.}$$

p = initial pressure = 350 lb. square inch.

l = length rod.

D = diameter of cylinder.

The buckling load of this rod = C

$$C = \frac{S}{1 + a\ r^2} = \frac{67{,}000}{1 + \frac{710}{370}} = 23{,}000 \text{ lb. square inch buckling}$$

load, when considered as free ended.

$$r = \frac{l}{d} \text{ and } l = 2 \times 48.$$

$$a = \text{for mild steel } \frac{1}{370}$$

s = for mild steel 67,000 lb. square inch.

The total load on the piston = $78{\cdot}5 \times 600 = 47{,}100$ lb. which gives a factor of safety of 4·9.

But where do we find a connecting rod $3\frac{1}{2}$ in. diameter on this size of engine? Perhaps the rod could be considered as steadied by the piston to a certain extent, so that the value of l might be modified. This calculation makes no account of the centrifugal force, which increases the bending action. Flat connecting rods are used in the Westinghouse engine, as is the custom with some American steam engines. The small end of the connecting rod should be easy of access, and with a means of making a fine adjustment in a short time. This can best be done by means of wedge gear, a hole being drilled in the piston to enable a box spanner to screw up the wedge without drawing the piston. This fine adjustment will be appreciated by anyone who has had charge of gas engines. The objectionable knock is most tiresome to remedy unless suitable means are provided. This knock, of course, comes at the end of the exhaust stroke once per cycle.

The positive scavenge of the Premier engine is arranged to prevent any reversal of stress in the moving parts of this point, but in other engines a knock soon develops. A mean bearing pressure of 600 lb. per square inch is allowed on the gudgeon pin, the effective length being about 1·5 times the diameter. The large end of the connecting rod is undoubtedly best, made on the marine pattern. The brasses should be stiff enough and thick enough at the crown to prevent opening out. Some large ends are made forked, with a back half-moon brass to take the load. The objection of heavily loading a half-moon brass is well known to those who have had experience in this direction. It is not an uncommon thing for half-moon brasses to crack right along the crown. It is much easier to fit a marine brass on a flat tee-ended rod, and there is little likelihood of the brass cracking. The bolts for these brasses should be of sufficient diameter to take any undue load or shock which may come upon them, as, for instance, would be produced if the nuts become eased, or the brasses slack.

Several serious accidents have been the result of broken connecting-rod bolts, which can only be due to weakness or improper design at this point.

Methods of fixing the cylinder to the main bed differ slightly in horizontal engines. Large overhung cylinders are not to be recommended, especially when attached by means of a few bolts screwed up on to lugs cast on the cylinder jacket. In the event of a nut easing back instability sets in at once, which is not so apparent when a good stiff flange is used in place of the lugs. In many cases the jacket is cast in one piece, with a pedestal, on which it rests, the breech end being bolted on, only a slight overhang being necessary. A really good arrangement is to fix the cylinder by means of longitudinal flanges, cast on the jacket on either side, and about level with the centre line of the cyclinder. Loose breech ends should always be fitted, greater soundness of the casting being thus ensured.

A hand hole, with removable cover, is a great convenience for washing out the water jacket of a breech end, as this casting contains many pockets between the ribs where lime and dirt can accumulate. It is most important that the castings of gas-engine cylinders be well designed and proportioned in order to avoid undue internal stresses being set up in the foundry. The same applies to flywheels in which, for gas-engine work, the mass of the rims is very great in comparison to the remainder of the casting. Stresses in the boss are obviated by casting this part in, say, three pieces, the gaps being run up with metal and rings shrunk on after the wheel is cold. Owing to the fact that the flywheel receives energy during only one stroke in two revolutions at most, a heavy duty comes upon the keys. Not only has shearing to be considered, but the main tendency is for key-ways to nibble the edges of the keys. Large bearing area must be provided to meet this, and it is usual to fit two keys, a quadrant apart, to all large flywheels for gas engines.

Notes on Large Engines.

The Westinghouse Company are making now a new horizontal two-cylinder double-acting engine, direct-coupled to an alternator, with all the working parts in sight, a pair of such engines giving 1,500 B.H.P. At Walthamstow are four 100 horse power and three 250 horse power engines for use with Dowson gas. There is no trouble from noise or vibration, and the plant has never been shut down.

Six engines of 1,000 horse power, with natural gas, are at work in America. Each as four single-acting cylinders, 23 in. by 28 in. stroke, running at 100 revolutions per minute, and driving compressors. Two engines govern by throttling the mixture, and four by automatic cut-off valves. The combined mechanical efficiency of engine and compressor is 82 per cent. At Philadelphia there are

10 engines of 280 horse power, each with 18 in. by 22 in. cylinders direct connected to triplex double-acting pumps, working against a pressure of 300 lb. per square inch.

In the author's opinion one of the best engines for small powers now on the market is that made by Fairbanks, Morse and Company, to which previous mention has been made. This engine can be run equally well on gas, refined or crude oil, or petrol. The engine has a high mechanical efficiency, owing to the particular method of construction. When governing the exhaust valve is held open, and by the same movement the air valve is held closed. This air valve has a very light spring, thereby allowing the cylinder to be filled with explosive mixture at practically atmospheric pressure at the end of the suction stroke. There is only one cam on the engine, and both tube and electric ignition are fitted.

In conclusion, the author earnestly hopes that in the near future users of large power in this country will give more consideration to gas driving, and that English gas-engine makers will endeavour to design and construct the reliable and simple vertical gas engine, which would no doubt create a demand. The majority of our gas-engine makers have apparently very little enterprise, and seem content to stick to their old patterns and small engines, and pay their 10 per cent. dividends, which will probably disappear in a few years, owing to the competition of American manufacturers.

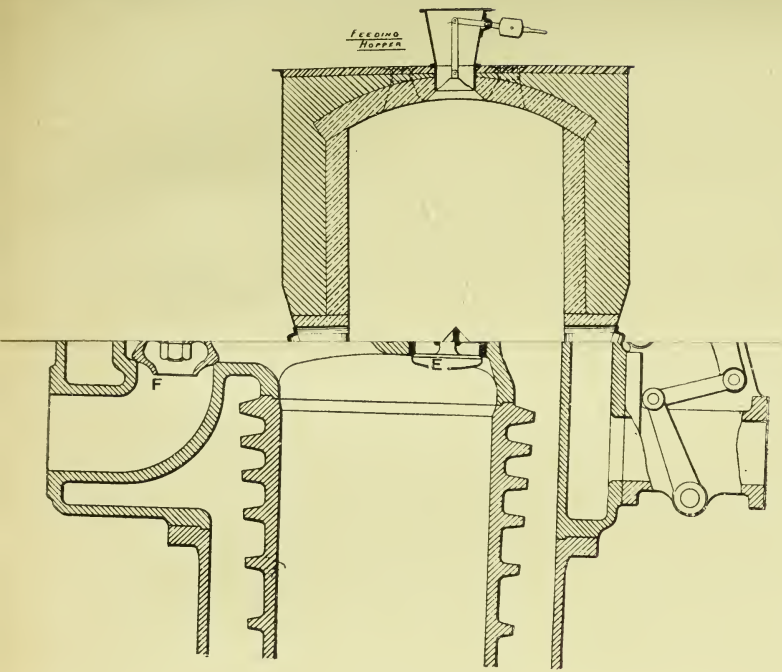


Fig. 2.

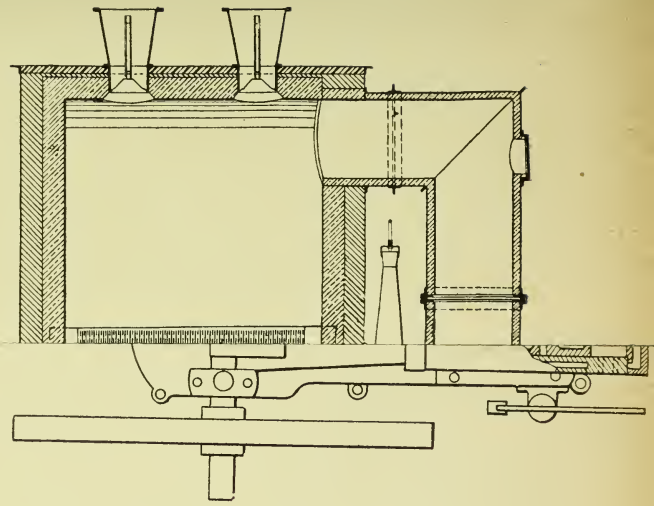


Fig. 3.

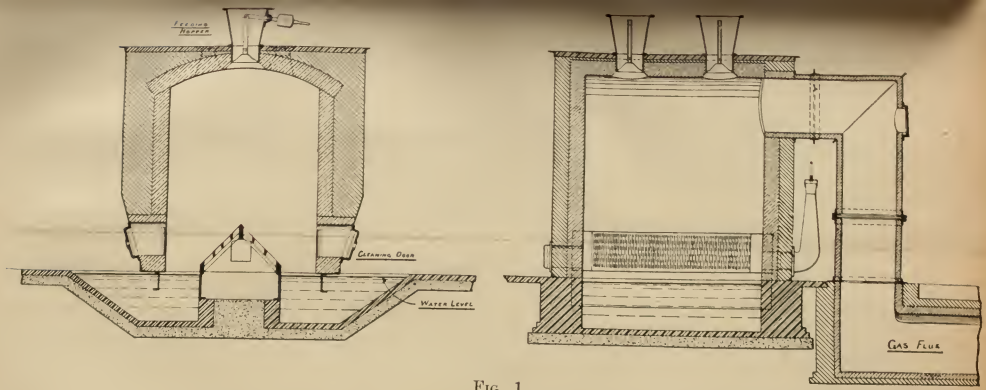


Fig. 1.

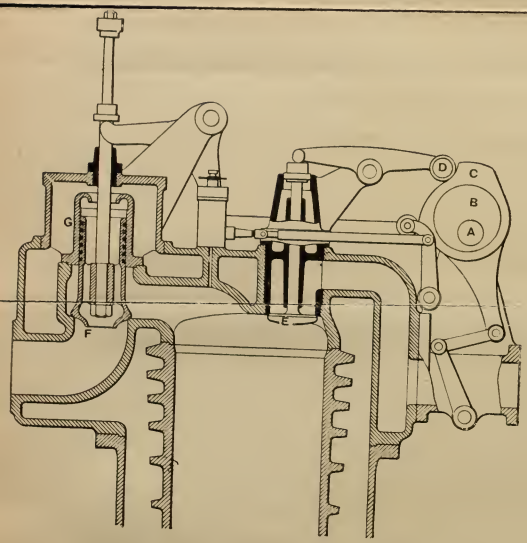


Fig. 2.

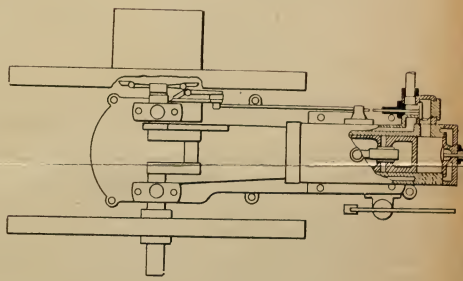


Fig. 3.

DESIGN AND TESTING OF CENTRIFUGAL FANS FOR INDUCED DRAUGHT AND OTHER PURPOSES.

By Wm. Gilbert, Wh.Sc. A.M.I.C.E.

[Read before the Society on April 2nd, 1903].

The present paper is, to a certain extent, supplementary to one read by Mr. Heenan and the author before the Institution of Civil Engineers in 1895. That paper dealt chiefly with the testing of the smaller varieties of fans and of the apparatus used for testing fans. The present paper describes installations of fans of larger sizes, designed on the principles laid down in the previous paper, and particulars of some tests are also added.

Suppose we take an ordinary type of double inlet blowing fan, the revolving portion of the fan (called the fan centre) being 28 in. diameter by 13 in. wide. Let the fan run at a constant speed, taking air from the atmosphere and discharging into a rectangular wooden box of the dimensions indicated in fig. 1. Let a water gauge be provided, and connected to a pipe passing to the centre of the box, the end of the pipe being provided with a flat plate to prevent inductive action by the air stream passing it. The gauge A records the actual pressure, or compression, set up in the box ; it takes no account of any water gauge due to velocity.

Suppose the fan to run at a constant tip speed of 12,000 ft. per minute, and first let the outlet of the box be closed so that no air is delivered.

The gauge A will indicate a compression of about $11\frac{1}{2}$ in. of water.

Next suppose a sharp-edged circular orifice, of 14·9 in. diameter, to be fixed at the end of the box, the tip speed of the fan being 12,000 ft. per minute, as before.

The fan will now deliver about 8,000 cubic feet of air per minute, but since a portion of the total water gauge produced by the fan is wasted in overcoming the resistance of the fan itself to the passage of the air through it, the compression in the box will have fallen to 8 in. of water. During the time the outlet of the delivery tube was closed, with no air being delivered, the efficiency was, of

course, nothing. But when the fan is passing 8,000 cubic feet of air per minute at 8 in. water gauge, as in fig. 2, the horse power of the air, reckoned by the product of the pressure and volume, is 10·0, and the efficiency of the fan is about 66 per cent., 15 H.P. being required to drive the fan.

When the end of the box is fully opened gauge A shows that the air is under no compression whatever. But the amount of air discharged has increased to 13,700 cubic feet per minute, the tip speed of the fan being 12,000 ft. per minute, as before.

Since the air is not compressed, but merely expelled at atmospheric pressure, the efficiency reckoned on the compression produced is 0. Since, then, the efficiency for no delivery and for maximum delivery is zero, there is necessarily an intermediate delivery at this particular tip speed of 12,000 ft. per minute, for which the efficiency reckoned on the compression produced on the air is a maximum.

The results of the preceding experiments may be exhibited by a diagram as follows:—

Take 2 axes $o\ x$ and $o\ y$ at right angles (see fig. 4), and for any size of opening at the end of the delivery tube set off along $o\ x$ the volume delivered by the fan, as $O\ a$ for the area of opening in fig. 2, when the delivery was 8,000 cubic feet per minute. On the ordinate $a\ c$ set up $a\ d = 8$ in., the compression produced at that delivery, $a\ e$, to represent the B.H.P. required to drive the fan, and $a\ g$ the calculated efficiency.

Mark off other values of the compression, B.H.P. and efficiency at 0, where the delivery is zero, at b where the delivery is 13,700 cubic feet per minute, and for any other volumes which have been obtained by the use of other diameters of orifices. The curves shown in the figure may then be drawn.

The above curves are for one particular tip speed of 12,000 ft. per minute, but unless considerable accuracy is required it is only necessary to experiment at one speed, because experiment shows that for any given size of orifice—

(1) The air discharged varies as the speed;

(2) The compression produced varies as the (speed)^2. The mechanical efficiency, however, is not very uniform, but increases with the speed.

Turning again to the experiment shown in fig. 2, the B.H.P. given to the fan and the compression produced are directly measured, but the volume discharged is calculated in the following manner: The compression in the box is the same as that due to a water column of 8 in., or to an air column of 540 ft., since at a temperature of 60° Fah., and a pressure represented by a height of barometer of 30 in. of mercury. one inch of water column is equivalent to approximately 68 ft. of air column. The velocity of efflux from the orifice is that due to a free fall from the height of

544 ft.; that is, 187 ft. per second. Allowing a coefficient of contraction of 0·64, the effective area of an orifice of 14·9 in. diameter is 0·71 square feet, and the discharge is thus 8,000 cubic feet per minute.

With regard to the correct value to assign to the coefficient of contraction, some experiments made by the Prussian Mining Commission in 1884 are quoted by Mr. Bryan Donkin in a paper in the Proceedings of the Institution of Civil Engineers, vol. cxxii. The Commission experimented on two orifices of 7·03 in. and 9·96 in. diameter, and determined the correct value of the coefficient of contraction as 0·64.

Referring again to the characteristic curve, fig. 4, the orifice of 14·9 in. diameter, as represented by the ordinate *a c*, was roughly the best resistance against which the fan, at this particular tip speed, should work. A smaller orifice would raise the compression or water gauge, but the volume of air delivered would be reduced, so that the proper output of the 28 in. by 13 in. fan, at a tip speed of 12,000 ft. per minute was 8,000 cubic feet per minute at 8 in. water gauge.

Formulæ for Output of Fans.

The area of the centre section of a fan—that is, the rectangle formed by the diameter and width of the fan centre—forms a convenient method of comparing different sizes of fans, as regards the volume and water gauge produced.

Let V = tip speed in feet per minute

i = compression in inches of water

q = volume discharged in cubic feet per minute, per square inch of centre section.

Then for the orifice of 14·9 in. diameter, as represented by the ordinate *a c*, it will be found by calculation that

$$V = 4240\sqrt{i} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$q = \frac{V}{545} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and these relations are fairly constant for fans of all ordinary dimensions, of similar design and for all the speeds used in practice, when the fan is giving what may be termed its best working output.

Turning now to tests of some fans recently made, fig. 5 shows a fan designed for blowing smiths' fires and cupolas. This fan is 18 in. diameter, and has a centre section of 50 square inches. It would ordinarily be used for water gauges up to 16 in.

This fan was tested by the author in London, using an apparatus similar to that illustrated in figs. 1 to 3, but owing to the small size of the electric motor used for driving, it was not possible to use a higher tip speed than 4,400 ft. per minute.

The fan centre has 10 vanes and 10 half vanes, bent forward at the periphery in the direction of motion.

Fig. 6 shows the characteristic curve obtained at a tip speed of 4,400 ft. per minute.

Three orifices of 4 in., 5 in., and $5\frac{15}{16}$ in. diameter respectively were used as indicated by the ordinates on the figure. The orifice of 5 in. diameter represents the best output of the fan at this tip speed, and it will be found that for these conditions

$$V = 3535\sqrt{i}$$

$$q = \frac{V}{495}$$

This fan being designed for pressure rather than volume, the fan centre is made relatively narrow.

It will be seen that the water gauge is obtained for a lower tip speed than in the case of the 28 in. fan previously referred to.

The highest efficiency reached, 42 per cent., is somewhat low, but the explanation is as follows:—

These fans are intended to run at a tip speed of 10,000 ft. to 15,000 ft. per minute; also the effective work done by a fan increases proportionately to the cube of the speed, but the frictional resistances do not increase in that ratio. Hence the mechanical efficiency rises with increase of speed. The fan being also a narrow one and the volume delivered comparatively small, the disc friction of the sides will be of greater relative importance than in the case of wider fans.

But the fan is more suitable for the particular purpose of producing a small volume at a high water gauge than a wider fan would be.

Fans for Induced Draught.

Within the past few years fans have been largely used in electric lighting stations and other places to assist the chimney in producing draught for the boilers.

Their use is generally due to one or more of three reasons:

1. Electric lighting stations generally have a period of maximum load, which lasts only for a short time. Fans are often installed to force the boiler for this short period, thus enabling a less number of boilers to be used. They are also useful to assist in raising steam rapidly should fogs suddenly occur.

2. In stations where superheaters or economisers or both are used, the gases may be reduced to a very low temperature before leaving the economiser by the use of a fan, and considerable economy results.

3. Many electric lighting stations have been extended far beyond the size originally intended, and thus flues and chimneys become too small. Consequently the boilers cannot make steam, and a fan is usually installed.

The fans now to be described are a selection of those which have been designed by Mr. Hammersley Heenan and the author to suit the conditions laid down by the engineers of the various electric lighting stations where they are installed.

Figs. 7 and 8 illustrate one of six similar sets supplied to the Charing Cross and Strand Electric Lighting Company, the general arrangement being designed by Mr. W. H. Patchell, the chief engineer to the company. The fan illustrated is applied to one Hornsby water-tube boiler having a total grate area of $52\frac{1}{2}$ square feet. In this station the fans draw the products of combustion through the boilers and economisers, and discharge them into a wrought-iron trunk which runs across the range of boilers and finally discharges into a brick chimney.

The fan centre is 5 ft. 6 in. diameter by 1 ft. 8 in. wide, the area of the centre section being 1,320 square inches. It is direct connected to a motor manufactured by the Electrical Construction Company, of Wolverhampton. The bearing at the fan inlet is self-oiling, and the oil reservoir is water-jacketed. The upper half of the bearing can be removed without breaking any pipe connections. The end of the shaft is also drilled so that a small current of cold air continually passes to the centre of the fan where there is a suction. This assists to keep the shaft end cool.

This fan was recently tested by the author, using the arrangement shown.

At the fan outlet and at the point of its discharge into the main flue a $\frac{1}{4}$ in. wrought-iron plate was inserted, as indicated at A B. The plate contained two sharp-edged circular orifices each 2 ft. $0\frac{1}{16}$ in. diameter.

The water gauges, *c*, *d*, and *e*, record the compression above the plate; the gauge *d* was provided with a non-induction tip, and was arranged to slide completely across the width of the outlet. The gauges *e* and *c* consisted of iron pipes finished flush to the inside of the plate, and to which water gauges were fixed in the usual way.

The pressure, or vacuum, below the plate was recorded by the gauges *a*, *f*, and *b*. Gauge *a* had a non-inductive tip, and could move across the entire width of the trunk; the gauges at *f* and *b* terminated in pipes which finished flush with the inside of the trunk.

The vacuum at the fan inlet was measured by the gauge *g*.

The test was of one hour's duration, four sets of observations being taken. Each set of gauges gave very similar readings, which only varied slightly throughout the trial. The average reading is therefore given. The results are as follows:—

(1) Periphery speed of fan, 6,720 ft. per minute.

(2) Mean temperature of gases entering fan, 460° Fah.

(3) Vacuum at fan inlet = 1·32 inches.

(4) Compression above plate = 0·82 inches.

(5) Vacuum below plate = 0·02 inches.

(6) Effective head at orifices = 0·84 inches.

(7) Water gauge produced by fan = pressure at outlet − pressure at inlet = 0·82 + 1·32 = 2·14 inches.

There were two orifices each 2 ft. $0\frac{1}{16}$ in. diameter.
Effective area, allowing coefficient of contraction of two-thirds = 4·21 square feet.

Calculation of Gas Velocity Through Orifices.

Let t = temperature of furnace gases in deg. Fah.

T = absolute temperature of furnace gases in deg. Fah.

i = effective water gauge at orifices.

v = gas velocity through orifices in feet per second.

h_b = height of barometer in inches of mercury.

Now, $t = 460°$. $\quad T = 460° + 461° = 921°$.

$$v = \sqrt{\frac{251 \cdot 7 \times i \times T}{h_b}}$$

$$\therefore v = \sqrt{\frac{251 \cdot 7 \times 0 \cdot 84 \times 921}{30}} = 80 \cdot 8 \text{ ft. per second.}$$

Hence discharge through orifices.

$$= 4 \cdot 21 \times 80 \cdot 8 \times 60 = 20{,}309 \text{ cubic feet per minute.}$$

Now, the effective water gauge produced by the fan was 2·14 inches.

Hence the effective work done by the fan.

$$= \frac{20309 \times 2 \cdot 14}{6352} = 6 \cdot 83 \text{ H.P.}$$

Dividing this by 14·06, the E.H.P. given to the motor, we get

$$\left.\begin{matrix}\text{combined efficiency} \\ \text{of fan and motor}\end{matrix}\right\} = \frac{6 \cdot 83}{14 \cdot 06} = 48 \cdot 6 \text{ per cent.}$$

Some little doubt was felt with regard to tests of a similar nature to the above on account of the meagre data available to fix the coefficient of contraction for the size of orifice used, although the figure 0·64 has been carefully established for orifices as large as 10 in. diameter. A check on the result of the trial was therefore obtained in the following manner: Mr. W. H. Patchell, the chief engineer of the station, had made many careful boiler and fan trials, using a method for determining the volume of the furnace gases which depends on their chemical analysis. This method was applied to determine the volume of gases passing through the fan during the fan trial just described. The two tests began at the

same time and were of the same duration. The method of procedure may be summarised as follows:—

The coal was analysed and the amount of carbon per pound of coal determined ; in this case the carbon was 87·24 per cent.

The furnace gases were analysed every 15 minutes, the mean result being as follows :—

C O_2	9·76 per cent.
O	9·88
C O	none.
N	80·36.
	100·00.

Now, the free oxygen in the furnace gases is a measure of the excess of the amount of air above that necessary for complete combustion ; the total air used is thus found to be 1·9 times the theoretical quantity, and the analysis of the furnace gases may be wrttten :—

C O_2	9·76.
Air	47·96.
N	42·28.
	100·00.

The weight of 100 cubic feet of the furnace gases is next calculated, and also the weight of carbon in 100 cubic feet.

The weight of furnace gases for 0·8,724 lb. of carbon is next obtained, and then the number of pounds of air used per pound of coal is known,

The amount of coal used per minute is measured, and hence the volume of furnace gases in cubic feet per minute at the temperature observed at the fan inlet can be calculated.

The chemical test was carried out by Mr. J. F. Brown, the resident engineer at the Lambeth Station of the Charing Cross and Strand Electricity Company, assisted by other members of the staff.

The volume of the furnace gases at 460° Fah. was determined by them to be 19,858 cubic feet per minute, a figure which agrees well with that of 20,309 cubic feet per minute determined by the author.

The coal burned per square foot of grate area per hour was 45·7 lb., and 21·42 lb. of air were used per pound of coal.

In making tests of induced draught fans by the orifice method there is often not opportunity to change the orifice, so that the size of orifice which will give the maximum efficiency or which will be most suitable has to be calculated beforehand.

Formulæ for Output of Induced Draught Fans.

With reference to the formulæ on which the output of induced draught fans depend, it is necessary to take account of the fact that furnace gases have less specific gravity than air.

Dealing first with the formula connecting periphery speed and water gauge, we have for cold air—

$$V = 3535 \sqrt{i}$$

Now, referring to the diagram fig. 2, where the tip speed of the fan was 12,000 ft. per minute, a water gauge of 8 in. was maintained in the delivery box corresponding to a head of air of 544 ft. It will be found that the tip speed of the fan is approximately that which a body would attain by falling through the height of 544 ft., and this relation holds both for air and water, and therefore it may be expected to be true for furnace gases. But for a *given* water gauge the height of the corresponding column will be greater for furnace gases than for air, because the furnace gases have less density. Hence the tip-speed necessary to produce a given water gauge will be greater for furnace gases than for air, and the ratio, according to the laws of falling bodies, will depend on the square root of the heights of the respective columns—that is, the tip speeds necessary to produce a given water gauge will vary inversely as the square root of the densities of the gas in the two cases. But for furnace gases and air the densities will be inversely proportional to the absolute temperatures, so that the tip speed necessary to produce a given water gauge will vary directly as the square root of the absolute temperature of the gas.

Thus the formulæ—

$V = 3{,}535 \sqrt{i}$ for air at 60 deg. Fah. becomes for furnace gases at 460 Fah.

$$V = 3535 \sqrt{\frac{460+461}{60+461}} \times i = 4700 \sqrt{i}.$$

This compares with $V = 4590 \sqrt{i}$ as determined in the experiment on the fan illustrated in figs. 7 and 8.

Next, with regard to the formula for the volume delivered per square inch of centre section, the value for air at 60° is

$$q = \frac{V}{495} \text{ to } \frac{V}{545}$$

This formulæ is found by experiment to remain unaltered for furnace gases, but the value of V for a given water gauge will, as previously shown, be greater for hot air than for cold air.

The above result may be explained as follows :—

Referring to the characteristic curve, fig. 4, it will be seen that the volume delivered by a fan is limited by the fall in compression which takes place, as soon as the amount discharged is such that the air passes through the fan with relatively a high velocity.

This fall in water gauge is due to the obstruction presented by the fan itself to the passage of air through it.

Now, in the formulæ $q = \frac{V}{495}$ the quantity q really represents a velocity, and expresses the fact that at the output for which any fan is designed the velocity of the air through the fan centre is a constant fraction of the periphery speed; that is to say, the water gauge due to the resistance of the fan itself is a constant fraction of the total water gauge produced, in the case of all fans of similar type, when working at or near their best output. This result is, of course, not affected by the density of the gas; hence the same law holds for hot and cold air.

Turning now to a description of further induced draught fans, a diagram showed two sets supplied to the City of London Electric Lighting Company to fulfil conditions laid down by Mr. Frank Bailey, the chief engineer. Each fan centre is 13 ft. diameter by 6 ft. wide, and the duty is 200,000 cubic feet of furnace gases per minute at $3\frac{1}{2}$ water gauge, the temperature of the gases being 600° Fah., and the corresponding fan speed 230 revolutions per minute. The fan is direct connected to a Sisson compound engine. There was only one position available for the fan, so that the engine had to be placed over existing pumps and a pipe race, whilst the fan stood over the main flue.

The fan draws the furnace gases from the main flue, and delivers them to the chimney as shown. Self-oiling water-jacketed bearings are provided, and, owing to the distance apart of the bearings, the fan centre is mounted on a steel tube 2 ft. diameter and $\frac{5}{8}$ in. thick. The journals are of wrought iron, the end of the journal being suitably flanged and secured to the shaft by turned bolts. The shaft is protected from the hot gases by inlet tubes, which do not quite fit the shaft, so that there is always a small current of cold air passing along the shaft and entering the fan inlet, where a suction exists.

Another diagram showed a single inlet fan supplied to the same company, the capacity being the same as in the previous case. The upper half of the fan casing is constructed of steel plate, the lower portion being formed in ordinary brickwork with a fire-brick lining.

The main bearing of the fan is water-jacketted and self-oiling, and lined with white metal. A tubular shaft is provided and a shield tube for the shaft, as in the case of the double inlet fans. The fan is direct connected to a Sisson compound engine.

Two other diagrams showed two double inlet induced draught fans, supplied to the Bournemouth and Poole Electric Lighting Company. Space was provided for a third fan to be installed later.

Each fan centre is 6 ft. 6 in. diameter by 3 ft. 3 in. wide, and was designed for 40,000 cubic feet of furnace gases per minute at 2 in. water gauge, the temperature of the gases being 300° to 350° Fah.

One fan is direct connected to a universal engine, and one to a motor manufactured by the Electrical Construction Company, of Wolverhampton.

A wrought-iron chimney, 75 ft. high and 6 ft. 6 in. to 7 ft. diameter, was also supplied.

In this arrangement the fans draw from two side flues connecting with the economiser, and deliver to a central flue leading to the chimney.

Suitable inlet and outlet dampers are provided.

There are two sets of tangent stays secured to the shaft by angle rings. Similar stays are fitted to the whole of the fans illustrated when they are direct connected to an engine, otherwise there is danger of damage to the fan, due to the uneven turning moment.

A flexible coupling is also usually fitted.

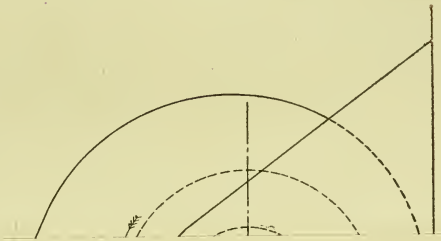
$V = 6720.\ \dot{t} = 2{\cdot}14$

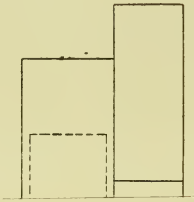
$Q = 20{,}309$

$q = 15{\cdot}4$

$\dot{t} = 460^\circ F$

$V = 4590\sqrt{\dot{t}}$





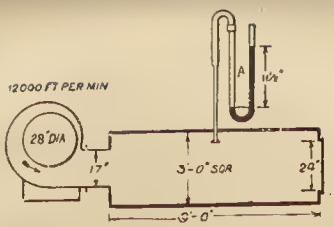


Fig. 1.

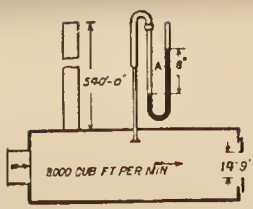


Fig. 2.

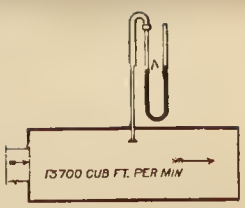


Fig. 3.

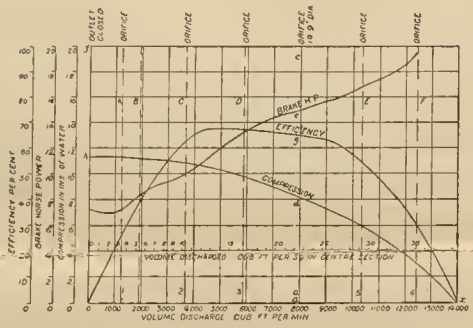

OUTLET CLOSED
ORIFICE
EFFICIENCY PER CENT
BRAKE H.P.
COMPRESSION IN INS. OF WATER
VOLUME DISCHARGED CUB FT PER SEC IN CENTRE SECTION
VOLUME DISCHARGE CUB FT PER MIN

Fig. 4.

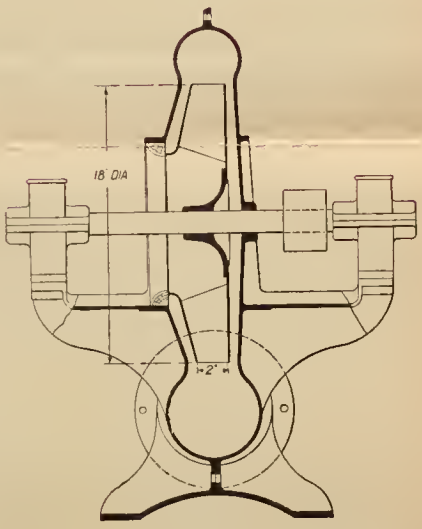


Fig. 5.

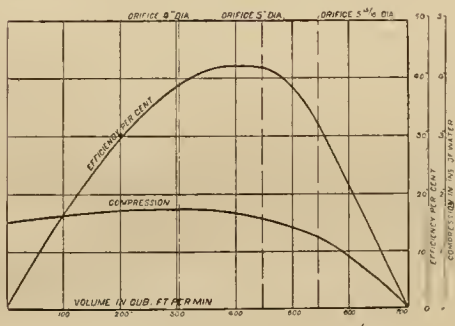


Fig. 6.

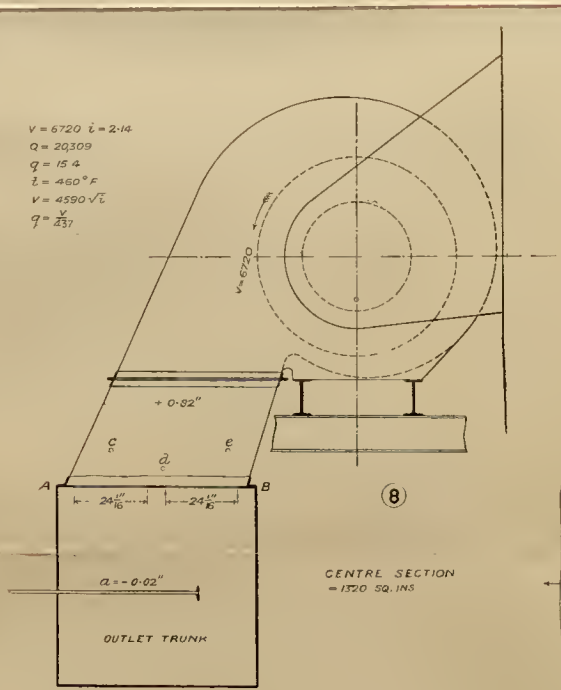


Fig. 8.

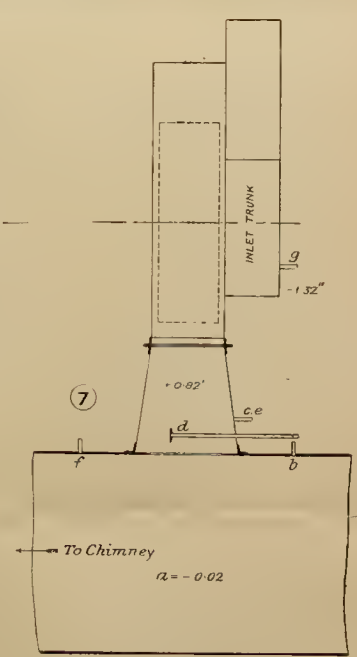


Fig. 7.

THE CHOICE OF STEAM BOILERS.

By Mr. C. E. Stromeyer, M.I.C.E.

[Read before the Society on Thursday, 7th May, 1903].

In my official capacity I have many inquiries from our members as to the choice of a steam boiler. Having thus had to give considerable attention to this subject the results arrived at may, I trust, be of some service in guiding others.

Forty years ago, my predecessor, Mr. Lavington Fletcher, evidently found himself in a somewhat similar position to mine. There were then in use many types of boilers, including watertube types, and there were also many different constructive details in one and the same type of boiler. Mr. Lavington Fletcher decided that, for most purposes, the Lancashire boiler was the most suitable, and he then carefully perfected its design. In our Manchester office is set up a full-sized front end of a Lancashire boiler, which he called the standard design. That design still holds the field, and in England, though not on the Continent, it is to this day the recognised standard, the only modifications which have been made are that the two longitudinal stay bolts are not now fitted, and in high-pressure boilers I have recently had to introduce a modification, which after three years trial can now be pronounced to be a satisfactory solution of the question of grooving in the end plates of Lancashire boilers. With high-pressure these plates have now to be made very thick, up to say 1 in., whereas thirty years ago they were rarely made more than $\frac{3}{8}$ in. thick. Modern high-pressure boiler end plates are therefore about twenty times more rigid than ancient ones. Most modern boilers are also heavily worked, and since condensing engines are more generally used there is of course much trouble with grease in boilers. Under these circumstances it was desirable to give relief by making modern high-pressure boilers as elastic as the older low-pressure ones, but without in any way weakening them. This has been effected by replacing 6 or 7 ft. of the plain furnace flues by corrugated flues. Instead of fitting these at the furnace end, where, due to the fierce fire on one side and scale on the other, the corrugated flues suffer so severely that they crack, they have been fitted at the back ends of the boilers, and as experience has shown they are thoroughly efficient in preventing

grooving around the furnace fronts. The difference of cost between two 7 ft. lengths of plain flanged furnaces and two equal lengths of corrugated furnaces is about £60.

The changed working conditions for boilers, notably the introduction of high-pressures, has led to many novel types being placed on the market, their designs were not always as safe as could be desired, and during recent years it has occasionally been my duty to insist on increased strengths or modified designs. Thus, for instance, builders of locomotive types of boilers were in the habit of fitting girder stays, which, according to the lowest standards, seemed excessively weak, and we have had to insist on increased scantlings, which now and then interfered with the internal accessibility. The very prolonged and apparently satisfactory experience of some boiler makers with girders which, according to mathematical formulæ, were only just capable of standing the test pressure, has had a very important influence on our decision not to ask for excessive strength, for although as guarantors of the safety of our members' boilers, we might be expected to consult only our own interests by insisting on excessive strengths, our position as consulting engineers to our members leads us to do our best for them in the way of safety, without running into unnecessary expenses for excessive weight of material.

As an old sea-going engineer I cannot but help feeling favourably inclined towards the general Marine type boiler, having return tubes, for have not these boilers now been in use for many years without, as far as I am aware, a single failure ? I am of course only speaking of those boilers of this type which are properly looked after. These boilers are less efficient than Lancashire boilers with economiser, but more efficient than Lancashire boilers alone. They are however expensive, being nearly twice as dear as Lancashire boilers of the same power, but they occupy only about half the floor space. It was therefore but natural that I should recommend this type where floor space was either not available or where it was very dear. A very serious difficulty soon presented itself. For inland towns it was found that the external dimensions had to he limited to 9 ft. 3 in. in length, and 11 ft. in diameter, and even where the transport was only by sea and then by road, and where consequently these dimensions might be exceeded, one has to make preliminary inquiries as to whether the weight is not too great for the roads, or rather for sewers and gas and water pipes under the roads.

A modified form of the Marine boiler is the dry-back return tubular boiler. The heating surface lost by having no combustion chamber, has to be provided for by additional tube-heating surface, and the result is a boiler of about the same size, power for power, as the Marine boiler, but weighing less. The brickwork combustion chamber occupies considerable floor space.

Water tube boilers are difficult to deal with. To begin with there are so many different ones. Mr. L. Robinson mentions 53

different types, many of these being of course designed to work at sea, would appear not to deserve our consideration, but that is a point of view which does not seem tenable, for the conditions at sea are certainly more arduous than ashore. It is true there is no scale in boilers on steamers as long as the condenser is tight, but then there is grease, which it is well known is worse than scale. Another difficulty as regards dealing with water tube boilers is that they are all monoplies, and whereas the patentees and their friends have an undoubted right, of which they avail themselves most freely, to mention all the good results which have been, and can be got out of these boilers, outsiders would be exposing themselves to considerable risks if they were to mention defects which have come to their knowledge, unless such information has been obtained by a public committee or in a Board of Trade inquiry. It is not my intention to enlarge on these inquiries, and I will only remark generally that water tube boilers are unsuitable with sedimentary feed, and where the water is not pure these boilers should be accompanied by a water purifying apparatus, the cost for which should of course be added to that of the boiler. It seems also to be a general experience that water tube boilers have to be designed with more heating surface than ordinary ones. It is claimed for water tube boilers that they are fit for higher pressures than either Lancashire, Marine, or other boilers, but these behave perfectly satisfactorily up to a pressure of 200 lbs., a measure which is already in excess of general requirements in factories, for it means steam pipes of wrought iron or steel, and troublesome reducing valves, because for many manufacturing processes require only low pressures. It is claimed for water tube boilers that they are quick steam raisers, but strange to say, even in electric power stations, where this argument must carry much weight, we find only the relatively slow steam raising boilers, those with large diameter tubes, whereas the express boilers, with small tubes, in which steam may safely be raised in 15 to 20 minutes, have apparently never been used. Those steam users, who have been carried away by the argument of quick steam raising, seem to have forgotten that no boiler responds more readily to sudden demands for steam than does the Lancashire boiler with its large water volume. Gradually this view is gaining ground, and in stations where water tube boilers are already installed, large cylindrical water carrying vessels, called thermal storers, are being added. Another point to which patentees of water tube boilers are not likely to draw attention is that any boiler, but more particularly boilers with wide water spaces, can easily be made to raise steam quickly if provided with artificial circulating arrangements, either pumps, as used at sea, which draw the cold water out of the boiler bottoms and deliver it above their furnaces, or else propellers in the boilers. In either case little power is required for circulation, and then of course the speed of raising steam is limited only by the heat obtainable from the furnaces.

The objection to this arrangement is that it is not so simple as lighting fires and waiting, but seeing that a very large quantity of coal must be wasted during the long hours which are now considered necessary for raising steam, it is more than probable that the fitting of circulating appliances, combined with rapid raising of steam, say one hour in a Marine boiler, and two hours in a Lancashire boiler, would result in a saving of fuel.

An important matter, and one which should not be overlooked when selecting a type of boiler is that of general economy, but unfortunately the subject is such an intricate one that there is no time to do more than give a general summary. I have, however, brought for distribution a few copies of my Memorandum for 1902, which dealt with the subject a little more fully than is here possible.

There are two important heat losses, radiation and heat carried up the chimney. Radiation is undoubtedly greater from water tube boilers than from Marine or Lancashire boilers, partly because of the relatively larger radiating surface, partly because the bricks are at a white heat, on the fireside, as against coverings of boilers being subjected only to the steam temperature. Assume that there is a constant loss of 5 per cent. of the full power heat supply, and suppose that a boiler is worked only eight hours out of the 24, then the loss by radiation is 15 per cent. of eight hours full power. At half power, or if the radiation is 10 per cent., the total loss is 30 per cent. If therefore we make a continuous power test between two boilers we ought to deduct 10 per cent. from the mean efficiency in the one case, and 20 per cent. in the other. The fairest boiler trials would be those carried out under the normal working conditions, and extending from the time the fires are lit to the time the fires are drawn.

The loss of heat up the chimney is intimately bound up with the efficiency of firing, and the ratio of heating surface to water evaporated. The efficiency of the heating surface of a boiler—no account being taken of radiation—is found, without weighing the coal, by substracting the temperature of the waste gases, as they leave the flues from the initial flame temperature, as calculated from the ratio of carbon and hydrogen burnt, and the amount of air contained in the gases, and dividing the difference by this initial temperature. Suppose that we are burning coke with a minimum admission of air—say 11·6 lbs. per pound of carbon—then the initial flame temperature will be about 5,000° Fah., and suppose that the temperature of the escaping waste gases is 500° Fah. above that of the ingoing air then there is evidently a loss of 10 per cent. up the chimney. If, as frequently happens, the waste gases weigh 26 lbs. per pound of carbon, then clearly the initial temperature of the flame is reduced to 2,500° Fah., and the loss up the chimney is 20 per cent. With smoky coal even more air is admitted, and we get losses of 30 and even 40 per cent., to which we have to add

5 to 10 per cent. for radiation, or 15 to 30 per cent for 24 hours trial, resulting in a total loss of 60 and perhaps 70 per cent.

These chimney losses can be reduced by efficient stoking, and by reducing the temperature of the waste gases. This is done by providing much heating surface or by economisers. When these latter are fitted the question of excessive air admission is of relatively a light importance, for supposing that the economiser is of ample size, and reduces the temperature of the waste gases to say 400 Fah., or say 540 above the air temperature, then the chimney losses with 20 and 30 lbs. of air per pound of fuel are 11 and 17 per cent., the difference being only 6 per cent. When the waste gases have a temperature of say 740° Fah. the losses are doubled, and the difference rises to 12 per cent. It is also found that the greater the excess of air supply the less efficient is the heating surface of the boiler, and it is safe to say that lightly worked boilers, having large heating surfaces—including economisers—may without serious loss be fired with a large excess of air, but hard worked boilers if treated in a similar manner, will show a very serious economic loss, and whereas we may burn smoky coal in the one, supplying it of course with much air, the smaller boiler has to be fired with smokeless coal.

The above remarks would lead one to think that all we want at present is a furnace which, while giving a smokeless flame, requires no more air than the theoretical amount, but that is not so. There is one further condition, and it is a very important one, viz., the flame temperature should not be excessively high, as it leads to boiler troubles, such as bulged furnaces and burst water tubes, a subject with which I dealt last year at the Institute of Naval Architects. I have recently thrown out a suggestion to adopt double combustion, but seeing that this paper already exceeds the usual limits, I will conclude by remarking that as matters stand at present, Lancashire boilers with economisers are doubtless the most efficient as regards economy and upkeep, but they occupy much floor space. Marine boilers, of course without economisers, are nearly as efficient, and seem to require practically no repairs; they occupy about half as much floor space as Lancashire boilers, but cost considerably more. Economic and water tube boilers are practically on a level as regards economy and floor space. In both cases the heavy brickwork is a constant source of expense not incidental to the two other types, and water tube boilers have this additional disadvantage, that except when lightly worked with non-sedimentary and non-greasy water, troubles are experienced with the tubes which, without counting the time wasted in stoppages, are a considerable expense.

Further numerical details are contained in the appended table:—

COMPARISON OF BOILERS AS REGARDS

TYPE.	Boiler Dimensions		Furnaces.			Coal Consumption per hour at 20 lbs. per sq. ft.	A Boilers surrounded by Flues. Dimensions over Brickwork, 9 ft. Stokehold and Valves 4ft. high.				Water evaporated per hour
	Diam.	Length	No.	Total Width	L'n'th		Width	Length	Height above floor	Total floor space	
	ft. in.	ft. in.		feet	feet	lbs.	ft. in.	ft. in.	ft. in.	sq. ft.	lbs.
Vertical Cylindrical	3 0	7 0	1	$2\frac{2}{3}$	dia.	80[1]	..	..	..	..	..
	6 0	15 0	1	5	dia.	400	..	..		..	..
Cornish	5 0	25 0	1	$2\frac{1}{2}$	5	250	8 2	37 0	9 9	302	1880
	6 0	28 0	1	3	6	360	9 2	40 0	10 9	367	2700
Lancashire..	6 6	28 0	2	5	5	500	9 8	40 0	11 3	387	3700
	7 6	30 0	2	6	6	720	10 8	42 0	12 3	448	5400
	9 0	30 0	2	7	6	840	12 2	42 0	13 9	517	6300
Lancashire Tubular	7 6	20 0	2	6	6	720	10 8	37 0[3]	12 3	395	5800
	9 0	20 0	2	7	6	840	12 2	37 0[3]	13 9	550	6700
Dry Back Return Tubular	9 9	9 6	2	6	6	720	12 11	24 6	14 1	317	5800
	11 0	8 9	2	7	6	840	14 2	23 9	15 4	337	6700
Marine Return Tubular	11 0[0]	9 3[0]	2	6	5	600	..	..	..	..	..
	12 0	9 8	2	7	$5\frac{1}{2}$	770	..	..	..	..	..
	13 0	10 0	3	9	6	1080	..	..	..	..	..
	14 6	9 9	3	$10\frac{1}{2}$	$5\frac{1}{2}$	1150	..	..	..		..
Locomotive	2 9	9 6	1	$2\frac{1}{2}$	$2\frac{3}{4}$	110[1]	..	..	..	..	..
	5 0	13 6	1	$4\frac{1}{3}$	6	520	..	..	..	..	..
	Width										
Babcock and Wilcox Water-tube Boilers	3 3	19 0	1	$3\frac{1}{4}$	5	325	8 3[2]	28 0	16 0	231	2430
	5 0	23 0	1	5	6	600	10 0[2]	32 0	18 0	320	4500
	8 6	23 0	1	$8\frac{1}{2}$	6	1020	13 6[2]	32 0	18 0	432	7650

0 These are the dimensions of the largest marine boiler that can be sent by rail.

1 Burning 15 lbs. per square foot of grate.

2 This width includes one 2 ft. side passage for tube sweeping purposes.

3 This length includes 6 ft. at end of boiler for tube sweeping purposes.

EVAPORATION PER SPACE OCCUPIED.

B Boilers lagged. Dimensions over lagging, and 6 in. clearance for inspection, 9 ft. stokehold, and valves 4 ft. high.				Water ev porated per hour.	C Economiser. Dimensions over brickwork and pit.			Total Water evaporated per hour.	Estimated steam production per sq. ft of floor space.			Assumed steam production per pound of fuel.		
Width	Length	Height above floor	Total floor space		No of Pipes.	Floor space Econ.	Floor space A.&C.		A	B	A.&C.	A	B	A. & C.
ft. in.	ft. in.	ft. in.	sq. ft.	lbs.		sq. ft.	sq ft	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4 8	9 9^5	11 0	46	400	..	..	..	..	..	8·7	..	..	5	..
8 0	12 9^5	19 0	102	2000		..	..	..	..	19·5	..	..	5	..
The Boilers are not set without Side Flues.					..	..	..	..	6·2		..	$7\frac{1}{2}$	..	..
							..		7·4	..	..	$7\frac{1}{2}$	..	..
Ditto.					64	70	457	4200	9 6	..	9·2	$7\frac{1}{2}$	..	$8\frac{1}{2}$
Ditto.					96	100	548	6100	12·0	..	11·1	$7\frac{1}{2}$	..	$8\frac{1}{2}$
Ditto.					128	125	642	7100	12·1	..	11·1	$7\frac{1}{2}$	..	$8\frac{1}{2}$
9 3	37 0^3	12 3	342	5400	..	..		..	14·7	15·8	..	8	$7\frac{1}{2}$	
10 9	37 0^3	13 9	398	6300	..	..	..	..	14·9	15·8	..	8	$7\frac{1}{2}$	
11 6	24 6^6	14 1	282	5400	..	..	..	..	18·3	19·1	..	8	$7\frac{1}{2}$	..
12 9	23 9^6	15 4	303	6300	.	..	..		19·9	20·8	..	8	$7\frac{1}{2}$	..
12 9	19 7^6	15 4	250	4830	..	..	..	..	..	19·3	..		8	..
13 9	20 0^6	16 4	275	6190	..	..	..	..	..	22·3	..	..	8	..
14 9	20 4^6	17 4	300	8700	..	..	..	..	..	29·0	..	..	8	..
16 3	20 1^6	18 10	326	9170	..	..	..	..	..	26·0	..	..	8	..
4 5	24 6^3	9 3	108	880	..	..	..	..	..	8·1	..	..	8	..
6 8	28 6^8	11 6	190	3900	..		..	..	..	20·5	..	..	8	..
No side flues, but two boilers placed side by side.										2 b'l'rs side by side				
7 6^4	28 0	16 0	210	2430	..	..	..	..	10·5	11·6	..	$7\frac{1}{2}$	..	..
9 3^4	32 0	18 0	296	4500	96	54	374	4800	14·1	15·2	11·8	$7\frac{1}{2}$	..	8
12 9^4	32 0	18 0	408	7650	48	70	533	8170	17 5	18·8	15·3	$7\frac{1}{2}$	..	8

[4] This width includes one 2 ft. side passage and half of an 18 in. division wall for two boilers.

[5] This length includes only a 6 ft. stokehold and 6 in. space at boiler back.

[6] This length includes 10 ft. stokehold instead of 9 ft., on account of overhanging smoke box.

TRANSACTIONS

OF THE

CIVIL AND MECHANICAL ENGINEERS' SOCIETY.

(Founded May 1859.)

45th SESSION 1903—1904.

EDITED BY

A. S. E. ACKERMANN, A.C.G.I., A.M.I.C.E., M.S.I.,

Hon. Secretary.

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THE

Civil & Mechanical Engineers' Society.

(Founded May 1859.)

25 VICTORIA STREET, WESTMINSTER, LONDON, S.W.

(Telephone, 244, Victoria).

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The Society is indebted to the Editors of the *Sanitary Record* and the *Surveyor* for the loan of the blocks illustrating :—

"General Notes on the London Traffic Problem," by J. F. J. Reynolds, A.M.I.C.E.

And to the Editor of the *Practical Engineer* for the loan of the blocks illustrating :—

"Dynamo and Motor Testing," by Prof. C. F. Smith, Wh.Sc., A.M.I.E.E.

On Thursday, April 7th, 1904, a paper was to have been read on "Friction Clutches and their Applicatlon to Motor Cars," by Mr. Holroyd Smith, M.I.E.E., but as this was given in the form of a lecture, the Council regret there is no matter to be published.

Civil and Mechanical Engineers' Society.

TRANSACTIONS—SESSION 1903-4.

PRESIDENTIAL ADDRESS.

FLUSHING TANKS.

[Read before the Society on Thursday, 1st October, 1903.]

By C. T. Alfred Hanssen, A.M.I.C.E., President.

The great epidemics of cholera which occurred in the middle of last century were, as many similar visitations have been, really blessings in disguise, and gave a great impetus to sanitary science, as all classes of society became interested in the prevention of such epidemics, and their causes were more thoroughly investigated than they ever had been before.

It was soon recognised that one of the principal causes of epidemics in towns is the pollution of the sub-soil by organic impurities, and that in order to prevent this pollution it is necessary to carry off all the waste products due to the vital processes of men and beasts as quickly as they are formed, and to render them inoffensive, by utilising them as manure or by getting rid of them as cheaply as possible in some other way. It is interesting to follow the steps by which it has been made possible to convey the solid and liquid refuse from the houses to the sewage outfalls, and to ascertain what *rôle* flushing and flushing tanks have played in it.

The sewers built before 1840 were as a rule mere underground passages with vertical sides, semi-circular top and segmental inverts, and no special effort was made to render them water-tight. The inverts were ordinary bricks set in sand like paving-stones and afterwards grouted with cement. In water-logged ground these sewers become surcharged with large volumes of sub-soil water; in dry ground the liquid parts of the sewage leaked into the sub-soil and polluted it, while the solid parts accumulated in the sewers and produced filthy decomposing deposits which had to be removed by manual labour.

The first attempt at remedying this state of things was simply to increase the size of the sewers, and this apparently met both difficulties by making the sewers able to convey more sub-soil water in water-logged ground, and by making it easier for men to get into them and clean them out in dry ground. As, however, the subsoil was still polluted by leakage, and the removal of sludge from the sewers by manual labour was expensive and extremely offensive, not only to the men engaged in the work, but also to the general public, another solution had to be found.

It is to the labours of the Sanitary Authorities of Westminster and Marylebone that we owe the knowledge of the first principle of sanitary sewers, namely, that they should be water-tight, and that they should be laid at such a gradient that the sewage will flow through them with a velocity of about 2·50 ft. per second, as this velocity was found experimentally to remove all deposits from the sewers and to make them self-cleansing.

The velocity of flow in the sewer does not, however, depend solely on the gradient at which they are laid, but also to a very large extent upon the volume of sewage flowing through them. A sewer may therefore be perfectly self cleansing when it is flowing half full or full and still be a sewer of deposit, if for some reason or other the volume of sewage estimated by the designer has not been forthcoming, or when the sewer has been designed to carry off a rainfall that only occurs during a few hundred hours each year, and leaves the sewer almost empty during the remaining time—say about 300 days out of the 365.

How great the difficulty is to get a sufficient volume of sewage during dry weather may be inferred from the fact that the sewage from 5520 persons will only fill a 9 in. pipe half full during the time of maximum flow with a velocity of 2·50 ft. per second, and that during the night the volume of sewage from such a population decreases to about one-fifth, and the velocity to 1·66 ft. per second. A fairly densely populated urban district has about 150 inhabitants per acre, and a 9 in. pipe is therefore amply sufficient for the dry weather flow of sewage from an urban area of 37 acres; where the water supply amounts to 30 gallons per head per day.

If the difficulty in getting small sewers properly filled is so considerable it may be imagined how much more difficult it is to fill a sewer during dry weather when it is built large enough to deal with a rainfall of 1 in. per hour, which for small areas with impervious surfaces may amount to 65 times the dry weather flow.

In the early days of sanitary engineering, when sewers were large and gradients flat, the question of flushing such sewers soon became a very important one. Egg-shaped sewers, 3 ft. high, have been put in streets where the maximum dry weather flow of sewage was quite insufficient to produce a current 3 in. deep

on the invert, and great difficulties arose from deposit of silt in such sewers.

The first attempts at flushing, which are still popular on the Continent, was by means of sluice gates built into the sewers themselves, which were closed periodically so as to allow the sewage to accumulate behind them. When a sufficient quantity of sewage was collected in this manner the sluice gate was opened by hand, and the whole volume of sewage swept through the sewer with a considerable velocity.

This way of flushing large sewers has not, however, proved a success, for although the effect upon the sewer in front of the sluice gate may be very considerable, the part behind the sluice gate is not sensibly improved by the flush, and considerable quantities of silt are deposited during the time of impounding, so that the upper part of the sewer, where flushing is most needed, gets into a worse state than it would be if no flushing were attempted.

Moreover the action of the flush produced in this manner only extends to a comparatively limited distance, and the silt and ditribus held in suspension when the flushing-water moves at a high velocity is again deposited in another part of the sewer when the velocity begins to fall below 2·50 ft. per second, forming banks of sand and grit in the sewer, which must again be removed, so that such flushing only results in moving the grit from one part of the sewer to another.

The difficulty in flushing a large sewer when the dry weather flow of sewage is small is indeed so great that from this reason alone it is desirable to adapt the separate system of sewerage, and to reduce the size of the sewers to the smallest possible dimensions by diverting the rain-water from them as much as practicable, and letting it flow through separate channels to the nearest water-course.

When the sewers are reduced to a moderate size it becomes possible to flush them efficiently, and a large number of automatic tanks are in use for this purpose.

Such tanks may be roughly divided into three classes :—

1. Tanks with mechanical movement such as tipping basins, and either alone for the whole flush or together with a syphon for starting the action of the same. (Fig. 1 and 2).
2. Tanks with "Vacuum" syphons, where the tank is discharged by producing a slight vacuum in the descending leg of the syphon by means of a thin stream of water overflowing from the tank, and falling through it. The water seal at the foot of the descending leg of the syphon in this case is seldom more than about 1 in.

3. Tanks with "Plenum" syphons, when the outlet pipe is provided with a deep water seal, sometimes as much as 36 in. deep, and the tank is filled with water to a corresponding height above the top of the syphon. The discharge takes place when the air enclosed and compressed in the syphon by the action of the water in the tank is allowed to escape either by means of a vent pipe or by forcing the water seal.

The first class of flush tanks depend upon the difference between the position of the centre of gravity when the tank is empty and when it is full of water.

The tank is mounted on trunnions so as to tip easily, and loaded so as to stand in a vertical position when empty, when filled with water the centre of gravity of the whole mass is shifted so that it falls in front of the trunnions, and the tank tips forward so as to discharge its contents into the sewer.

Such tanks are however somewhat noisy in their action; they are apt to stick, and the trunnions gradually wear out so that they are not now generally used.

In many flush tanks a small tipping basin is used for starting a larger syphon tank as in Shone's Flush Tank (Fig. 1). This tank, although it has many advantages, and can be used for flushing with crude sewage, has never come into general use, chiefly owing to the above-mentioned drawbacks.

The second class of flush tanks with "Vacuum" syphon is chiefly represented by the well-known Rogers Field Flush Tank (Fig. 2). This tank was patented in 1875, and has done good service in flushing sewers with clean water, and it is still extensively used in spite of being somewhat delicate in adjustment and liable to fail if the stand pipe should get out of the perpendicular or any dirt should accumulate on the dripping edge of the pipe.

The action of any syphon flush tank may be divided into four periods, namely:—(*a*) *The period of filling.* This should, in a flush tank, be as long as possible, so that a small driblet of water may be gradually accumulated and discharged with considerable force when the tank is full. (*b*) *The period of starting*, during which the level of water in the tank gradually rises above the top of the stand pipe to a height determined by the water seal at the bottom of the pipe. For a vacuum syphon this seal does not generally exceed 1 in., while for a plenum syphon it may be from 9 in. to 3 ft., accordingto the size and design of the syphon, allowing the water in the tank to rise to this height before the discharge commences.

In the vacuum type a slight vacuum is created in the vertical stand pipe when the water begins to overflow as the stream of water is directed towards the centre of the pipe,

and prevented from trickling down the sides, and a part of the air in the stand pipe escapes through the water seal at the bottom of the pipe. In this way the syphonage is established, and the discharge is started. For plenum syphons the action is somewhat different as the water in the long leg of the deep seal is gradually depressed until it reaches either the opening of a vent pipe as in Adam's Flush Tank (Fig. 3) or is expelled altogether as in Miller's or in Shone and Ault's Flush Tank (Fig. 4 and 5). But in order to do this, it is essential that the volume of air enclosed in the bell over the discharge pipe or in a hood in front of the same (Fig. 5) should be sufficient to displace the water in the long length of the syphon, when this air is compressed by the superincumbent water. The superincumbent water above the top of the syphon pipe then rushes out as soon as the plenum in the pipe is removed, and the syphon action is in this way established. (*c*) *The period of discharge*, which in order to give the best possible effect to the flushing water should be as short as possible. This is secured by using a large syphon pipe, working with a maximum head above the invert of the sewer, so that a large volume of water is discharged with a considerable velocity. As the quantity of water required to flush a given sewer varies as the square of its length, and directly as the velocity of discharge; this is a matter of some importance, which however is very frequently overlooked. (*d*) *The period of stopping the syphon action.* This is one of the most serious difficulties, especially in connection with plenum syphons, as the deep seal prevents air from entering freely into the long leg of the syphon, and restoring the atmospheric pressure therein. If this is not done the flushing action of the tank is entirely suspended, and an equilibrium is established, which allows the water in the tank just to reach the top of the syphon pipe and flow out at exactly the same rate as it flows into the tank. This action may continue for any length of time, and it is therefore essential that some device should be used for compelling air to enter the syphon after each discharge, and effectually to break the action of the syphon. The three "Plenum" Tanks already referred to (Fig. 3, 4, 5) show three such devices which may be said to be representative of all tanks of this class.

Adams' Flushing Tank (Fig. 3) works with a vent pipe A, reaching above the water in the tank and extending to a few inches below the level of the water seal. When the water in the U bend is forced down to this point by the plenum in the pipe, the compressed air escapes, and the syphon is started. Towards the end of the discharge this vent pipe serves to admit air into the long leg of the syphon, and thus to stop the action of the syphon. The diameter and immersion of the vent pipe is therefore of great importance for the proper working of the tank, and any accumulation of dirt in this pipe would seriously interfere

therewith. The vent pipe is therefore arranged in such a manner that it can be easily cleaned, and the tank should not be used for dirty water, but is very reliable and effective when used for flushing with reasonably clean water.

Miller's Flushing Tank (Fig. 4). In this tank the vent pipe is dispensed with, and the water seal, which is very deep, is forced by the air pressure in the syphon pipe, when the water in the tank reaches its proper level. In order to admit air into the pipe C when the discharge is completed, a small auxiliary syphon S is provided, the short leg of which reaches a little below the bell E of the main syphon. This auxiliary syphon continues to discharge after the main syphon has stopped, and lowers the final water level, so that air enters under the bell E and fills the pipe C. The tank works very well indeed so long as the auxiliary syphon is clean, but this syphon is easily blocked and somewhat difficult to clean out again.

Shone & Ault's Flushing Tank (Fig. 5) is in principle somewhat similar to the Miller syphon, but avoids its drawbacks by using two complete full size syphon inlets, one of which is somewhat higher than the other. The first or deeper inlet continues to discharge until air can enter freely through the second or upper inlet, and thus breaks the syphon by introducing a large volume of air into it. This syphon has therefore the advantage of offering no impediment to the passage of crude sewage, and may therefore be able to realise the Sanitary Engineer's ideal of collecting the small driblets of sewage from a number of houses at the dead ends of the sewers, and sending them out in a strong flush, and in this manner to keep the upper parts of the sewers clean without resorting to the use of large quantities of potable water.

The Author has often felt the necessity of some formula for determining approximately the quantity of water required for flushing a given sewer, or the distance to which any given flush tank may be relied upon to clean a sewer effectually, and last year, in submitting an important sewerage scheme to the Russian Government, it became very desirable that such a formula should be included in the proposals, as the advisers of that Government attach greater importance to theoretical calculations than is generally the case in this country. The working out of such a formula, however, is somewhat difficult, as the amount of flushing water required does not only depend upon the length and diameter of the sewer, but also on its inclination and upon the initial velocity with which the sewage is discharged.

Mr. S. H. Adams, Assoc. M. Inst. C.E., has carried out a very complete series of experiments on the effect of flushing sewers, and he has been kind enough to send the Author a number of diagrams, giving the results of these tests. The Author has therefore proposed the following formulæ based upon these experiments:

$$l = 0{\cdot}291 \sqrt{\frac{Q(v_1^2 - v_2^2)}{a(S_m - S_2)}}$$

$$Q = \frac{11{\cdot}8 \times l^2 \times a(S_m - S_2)}{v_1^2 - v_2^2}$$

in which

l = length in lin. yards of the sewer to be flushed.

The final velocity of the flushing water to be v_2, which, in order to be effectual, should not, as a rule, be less than 2·50 ft. per second.

v_1 = initial velocity of water in feet per second, as it issues from the syphon. It depends upon the drop h (in feet) from the centre or mean water level of the flush tank to the centre of the sewer or $v_1 = 6{\cdot}0\sqrt{h}$.

v_2 final velocity of flushing water.

S_m = sin. of inclination theoretically required for giving the mean velocity v_m to the flushing water.

For a velocity varying from v_1 to v_2 the mean velocity would be $v_m = v_2\left(1 + \log_e \frac{v_1}{v_2}\right) - \frac{v_2^2}{v_1}$, on the supposition that the velocity decreases according to a hyperbolic curve, which appears approximately correct according to Mr. Adams' experiments :—

S_2 = actual sin. of inclination of the flushed sewer.

a = sectional area of the flushing water as it enters the sewer.

Q = quantity of flushing water available or required in cubic feet.

In the above formula the expression $Q(v_1^2 - v_2^2)$ represents the momentum of the body of water issuing from the flush tank between the limits of velocity v_1 and v_2, while the expression $a(S_m - S_2)$ represents the resistance acting through the length l, and gradually absorbing the momentum of the water. The retardation due to S_m is to some extent compensated by the actual inclination of the sewer, so that in a very steep sewer, where S_m becomes equal to S_2, the initial velocity may be maintained throughout the whole length of the sewer.

In order to obtain correct results to the value of S_m, should be found from Kutter's formula, which however may be simplified to the following expressions, and which for varying diameters and co-efficients of roughness (n) are as follows when D = diameter of sewer in feet :—

for sewers 7 in. to 12 in. diam. $n=0{\cdot}0115$, $S=\left(\frac{\sqrt{D}+0{\cdot}96}{99{\cdot}6D}\right)^2\times v^2$

for sewers 12 in. to 15 in. diam. $n=0{\cdot}0112$, $S=\left(\frac{\sqrt{D}+0{\cdot}93}{101{\cdot}6D}\right)^2\times v^2$

for sewers 15 in. to 18 in. diam. $n=0{\cdot}0107$, $S=\left(\frac{\sqrt{D}+0{\cdot}89}{105{\cdot}8D}\right)^2+v^2$

for sewers 18 in. to 24 in. diam. $n=0{\cdot}0105$, $S=\left(\frac{\sqrt{D}+0{\cdot}88}{107{\cdot}0D}\right)^2\times v^2$

for Brick sewers $n=0{\cdot}0130$, $S=\left(\frac{\sqrt{D}+1{\cdot}08}{90{\cdot}45D}\right)^2\times v^2$

The agreement between the results observed by Mr. Adams and those found from the above formula is very close, as may be seen from the results given below :—

No.	Initial Velocity. v_1	Final Velocity. v_2	Mean Velocity. v_m	Sin of Inclination of Sewer. S_2	Sin Ind. due to v_m. S_m	Diameter of Sewer. Inches	Quantity of Flushing Water. Q	Length of Sewer in Yards. Calculated from formula. Yds.	Length of Sewer in Yards. Observed by S. H. Adams. Yds.
1	6·50	2·50	3·93	0·004	0·0092	9 in.	56·26	275	266
2	5·00	2·00	3·03	0·005	0·0055	9 in.	75·50	782	800
3	7·25	2·30	4·22	0·0017	0·0049	15 in.	1326·00	1162	1166

The Author regrets that he has as yet been unable to verify the formula by further independent tests on sewers under various conditions, but suggests that other Engineers may be able to do so. When long lengths of sewers are laid at a uniform gradient it would be comparatively easy to ascertain how far the formula holds good for sewers of different sizes laid at various gradients.

It appears, however, from the formula that the effects of the flushing water only increases as the square root of the quantity, so that greater results may be expected from two or more small tanks placed at suitable intervals than from a single large tank at the head of the sewer. The effect of the flush is further increased directly in proportion to the initial velocity, and every effect should be made to obtain the highest possible initial velocity by utilizing the available head, and by using syphons of ample size. Finally it should be observed that to lay the sewers at a steep gradient will greatly assist the action of the flush tanks, while flat gradients increase the resistance of the flow of the flushing water in proportion to the average velocity, and therefore go a long way toward neutralizing the effect of the high initial velocity.

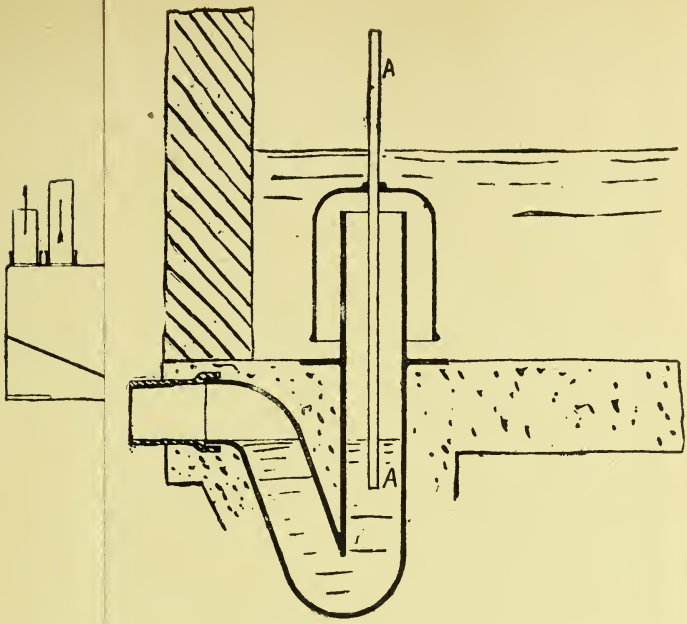


Fig. 3.

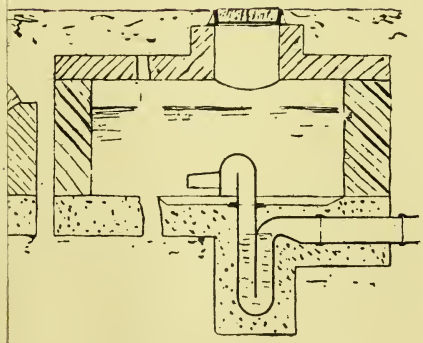


Fig. 5.

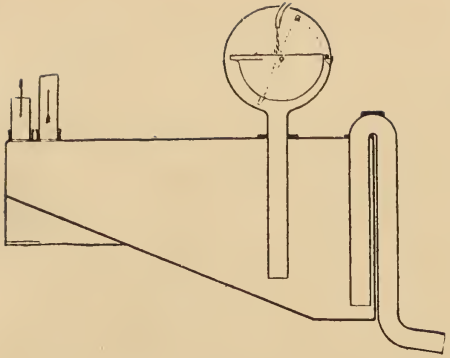


Fig. 1.

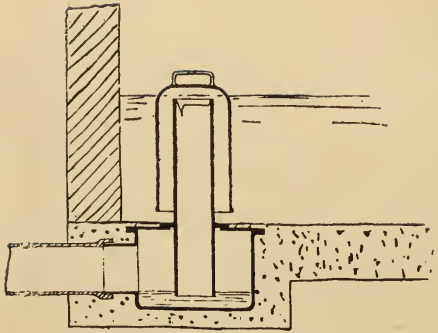


Fig. 2.

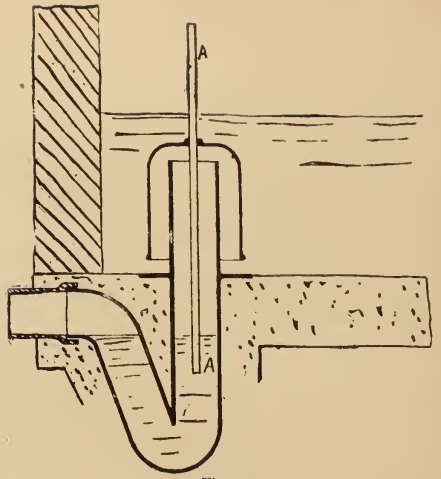


Fig. 3.

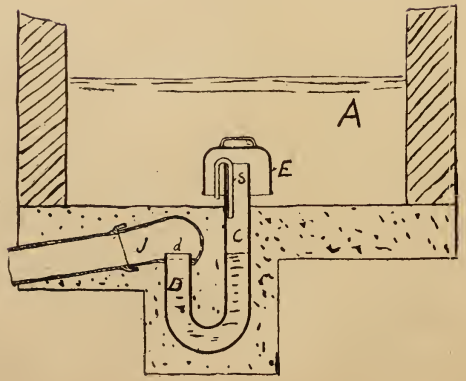


Fig. 4.

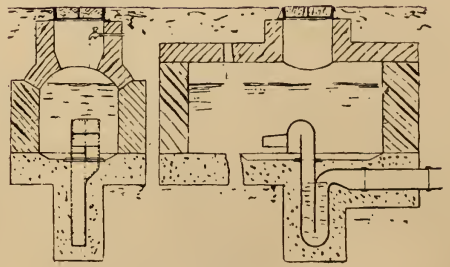


Fig. 5.

FOUNDATIONS.

By H. T. H. Siccama, M.I.C.E.

[Read before the Society on Thursday, November 5th, 1903.]

The foundation is that part of a structure which supports the part built to fulfil an intended purpose. It is not always clear where the foundation ends and the superstructure begins; for instance, when foundations are utilized for cellars. As a rule, the foundations are below the level of the surrounding ground. The need of foundations indicates that the soil to be built upon is too soft or untrustworthy to carry, unprepared, the weight of the building, for on rock or other incompressible surfaces no foundation is needed. On compact but still ductile clays, the total estimated weight of the structure gives the measure for the required width of the footings. But soils like clay in level strata, sand, gravel and stiff loam, where there is no danger of disturbance by running water, may be left out of consideration.

Foundations obtain their greatest importance in alluvial soils, where their cost is sometimes equal to that of the super-imposed structure. If alluvial soils consisted solely of the inorganic deposits of rivers and streams that formed them, a sufficiently hard bed to carry weights might in most instances be found but little below the surface; but this is seldom the case. This is easily understood if the mode of formation of a delta is considered. The growth of a delta at the mouth of a river flowing into a tidal sea, is a very complex proceeding, and subject to continual changes. The first effect is the formation of shallows on each side of the mouth and parallel to the direction of the river current as it leaves the unsubmerged coast line. These banks consist of matter precipitate from the volumes of river water flowing sideways and losing their acquired velocity on meeting the heavier seawater. The centre of the fresh water current continues seaward for some distance, and deposits its silt in the deeper water, forming a bar from where part of it is either carried sideways by littoral currents or up river again by the incoming floods, and eventually to side shallows. As these warp up more and more, the real river mouth is deplaced seaward, the surface gradient of the river becomes flatter, the current slower, the deposit in the river-bed increases, and the bar shallows. The river at last finding its outlet

insufficient, breaks through one of the side banks and makes a new mouth. The old bed being left without sufficient current, shallows, and the bar at its mouth no longer eroded, is raised by the surf acting on it, and overlaying it with sea-sand pushed up by the grounds well from the sea bottom. As soon as this sand reaches the surface, the sea wind dries it and blows it up into dunes, high enough to keep out the high tides, the old river bed is turned into a lake, at first brackish and then fresh.

The salt and other constituents of sea-water are precipitated or absorbed by plants that soon begin to appear in the stagnant water; first round the water edge, reeds or floating water lilies. This green band broadens, and at last covers the whole surface, and as the plants decay, grasses and morass plants cover the floating mass, thickening it; then trees with wide spread roots begin to grow on it, till their weight becomes too great for the floating soil. They either sink through to the bottom, or, a gale assisting, are thrown sideways, and so increase the thickness of the now tangled mass of vegetation. So the process goes on for some time, till river mouth number two undergoes a similar fate as the first, and the river seeking a new outlet breaks into the lagoon, covers the vegetation with layers of salt or sand. The sea in flood finds its way into it as soon as the river breaks through the side banks, kills what remains of plants, and turns the whole into a putrid, festering slough, till through another change by the river, it is again cut off from salt water. Then as soon as the old lagoon looses its salt, fresh water vegetation, marsh plants, reeds, trees, follow each other in covering the surface But below it, the hollows and depressions, above harder inorganic strata, are still filled with the remains of the former growths, intermingled with layers of sea clay or sand, river clays, and gravel, or other deposits.

In each successively abandoned river mouth the same goes on, and the delta spreads out fan-wise and seaward, composed of numerous compartments filled with mixed organic and inorganic stuff, and divided by ridges of clay, loam or sand. Through all these different marshes and lagoons, the river continually changes its course, dividing into two or more arms, abandoning a new outlet, or re-visiting an old one. It is the mixture of all sorts of stuff, in alluvial soils, inorganic and organic, in layers of varying thickness, and divided off in areas of irregular form and size, which causes such sites to be the most untrustworthy and difficult to be built upon, where human ingenuity in the matter of foundations is most called forth.

When in these swamps and marshes constructions of any weight were wanted, the first idea to suggest itself would be to distribute the load over as great a surface as possible, and this could be obtained by means of a raft. Where timber was abundant, beams were used; if heavier material were lacking, smaller trees and

branches intertwined served the same purpose. Such old raft foundations may still be found under ancient buildings. On the alluvial plains of British Guiana, first brought under cultivation by Dutch Settlers, some still exist to the present day. Even old brick windmills, chimney shafts on sugar estates, and the brick lighthouse at Georgetown, stand on rafts made of two or three tiers of heavy Greenheart or Mira baulks.

In the fens of the Netherlands and of Northern Germany are still some old farmhouses resting on an even less coherent bed than a thick matting of branches and faggots affords. Probably for the want of better material in the vicinity, layers of dried peat, cut in long pieces and in several tiers at right angles to each other, served as foundations. Not only for buildings, these spread out supports were used, as is proved by part of an old Roman road through a peat bog discovered some years ago, constructed almost entirely of logs lying close together in two layers, the lowest parallel to the axis of the road, the other across it, and the interstices filled in with smaller branches; a regular conduroy road, like some in the swampy districts of the United States at the present day. With the same idea, that of spreading the load sand foundations accord, as sand compressed in a confined space gives as hard a bed as can be desired for most purposes. In old alluvial soils, the different strata, as a rule, increase in compactness as they are lower down, and although the first few feet from the top may be so soft that cattle in wet weather get bogged in it, yet after this nearly liquid mud is removed, layers may be found which, although yielding, are capable of supporting some weights. What this may be must be ascertained by experiment, conditions being so variable that a hard and fast rule does not exist. On the green surface a galloping hare may shake the ground for thirty yards round, a few feet below it the soil will support a ton per square foot, while again a few rods off a quarter of a ton per square foot will settle down more than is convenient. Particularly in soils of such varying compactness, sand gives a very good support on condition that it is not scoured away by running water or blown away by the wind. The sand may be piled up on the surface by its weight compressing the mud underneath it, but a more workmanlike way is to remove the upper mud by digging a trench or a pit many feet wider than the foot of the buildings are to be, and going down to a harder layer. This trench or pit is then filled in with sand, which will settle downwards and sidewards till an equilibrium is obtained. As the top of the sand descends the soil round it heaves up in a sort of billows, often higher than the sand mound. Sometimes the sand not only compresses the layers below it, but pierces them and sinks down to considerable depths. If then borings are taken they show that the sand has made a way for itself in a very irregular way, very different at different cross-sections, mostly

in the form of a rounded body, bulging out here and there. This bulging out sideways may go on after there is no settling down observed, and then more sand should be supplied to fill up the space. It is curious to note that these after workings most often occur at night, and not seldom after the ground has been violently shaken by pile driving or otherwise. Stability once obtained, and neither sand nor surrounding ground moving, the top of the sand can be levelled off, and the footings laid on it. The peaty, boggy soils owe their character to the great quantity of water they contain. The trench or pit, therefore, will be filled by it, and the sand tipped in should reach to high above the surface of the surrounding sub-soil water, or else it will for an inconveniently long time be more like a quicksand than a sand plate. It is even advisable to heap a mound of an extra five or six feet over it to press the submerged bottom layer down, and then, if possible, to lower the water level. Even then the sand will remain compressible, and it is as well to give it a good ramming down before laying down the footings, or else the eventual settling will be more than convenient.

In the present day concrete is the best material for the footings, laid down in slabs. Where they are to carry a compact structure, like a tower or chimney, a few layers of cement mortar will be sufficient, but where it concerns long wall iron rods running lengthwise, bedded a couple of inches above the bottom in the concrete of the lower slab, and also a couple of inches from the top of the upper slab, will give great security against unequal settling and fissures in the walls.

The width of the footings and their thickness, and the sectional area of the trench must be determined by experiment on the spot. A trial pit filled with sand, on which a load of some heavy substance, is not expensive. It should, however, be of sufficient area to give a stable based to the load to be imposed on it, or else this will topple over or settle sideways, leading to erroneous conclusions.

Sand foundations are a very ancient device. Some Egyptian temples in the lower Nile delta are built on it. The builders placed little images of their gods and holy animals in their foundations, which seem to have answered very well, as most of these temples still stand, but now-a-days iron rods as described will perhaps inspire more confidence. In recent times sand foundations have again been used; for instance, under railway buildings and workshops on the North Coast of Java, for lines of railway in Holland, for the Law Courts at Georgetown, British Guiana, and so forth.

Another long-known system is that of piles. Even the lake dwellings of prehistoric times were principally built on them, driven vertically or nearly so, into the lake bottom; and united at the top by heavy timbers forming a floor for the huts.

The same type may still be met with in some coast villages in the tropics, that stand several feet above the surrounding water or land.

The white man's practice at present is to drive the piles down out of sight. It is curious to observe how erroneous ideas have crept in about the usefulness of a pile foundation. It is thought by many that the driving of a sufficient number of piles consolidates the soil, whereas it is just the reverse. The piles themselves and the shaking during the driving, destroy such cohesion in the different strata as may exist, and churn the whole up into a quagmire. If driven in great numbers, they really act like a raft, of which the beams are placed vertically instead of horizontally. This applies specially where the piles do not reach a layer hard enough to support them and their eventual load, in which case they miss their purpose, that of supporting a platform, like a table, on its legs. Many buildings stand out of plumb, because the whole mass below, piles and mud, is bodily pushed over through a lateral thrust or inadequate support, a heavy load on one side or an excavation. Some thirty years ago a dockwall in the Isle of Dogs slid sideways in this way.

Besides by buoyancy, the piles counteract gravity by the friction of the surrounding matter, however porous and soapy. In driving a long pile the first few feet may go down rapidly, seemingly by their own weight, and the rate of sinking after that becomes less at every subsequent blow, and then remains stationary. If in the end a hard stratum is not reached and the pile is left alone for twenty-four hours, it takes several blows before any impression is made, owing to the adherence of the soil to the surface of the pile, and should ramming be stopped after a few knocks only, the idea is given that the pile stands in firm ground. This leads to grave misapprehension, for when the full permanent weight of the building is at last super imposed, a considerable slowly progressing settling is observed going on for years, till at last the platform over the piles compresses the sub-soil sufficiently and acts like a raft more or less. Where piles are not driven down into holding ground, another inconvenience may be suffered, most of the piles already driven being pushed up again whilst others are put down near, even after they have already been fastened to the sleepers or stringers that are to support the wall footings. Where piles in this way remain, so to say, floating, it is useless trying to obtain increased stability by driving some in a slanting direction. But in every case the construction of the timber platform is of great importance, not only that it must be able to carry the weight of the walls between the piles, but it must bind these together so as to distribute the load evenly, and besides prevent the upper part of the long masts from bending sideways.

Another error is the use of a pile foundation where a hard sand plate is met with at little depth beneath the surface. An old

sand stratum is very difficult to pierce, and where this succeeds and the piles are not shivered and split before they are half-way down, the sand is all round distributed and broken up. Not much harm is done where the timbers are constantly submerged in fresh water, but where toredo navalis can get at it disaster is sure to follow, for the sand, disturbed during operations, ultimately settles down again, and leaves spaces filled with clean water, where the sinister worm soon enters. Where a foundation is intended to support a lock, and the hard sand plates are not too far down, it is preferable to tip the concrete in on to the sand bottom, if covered by water in hard lumps of stale or half-set mortar. In this way a water-tight dam is obtained, whereas in the other case some leak is sure to ensue between the sand surface and the lower face of the lock or sluice bottom.

Where a sufficiently hard strata is overlaid by soft stuff to such a depth that the longest procurable masts cannot reach it, wells can be used. This in a way is not a new invention either. In India wells have been known since time immemorial, under weirs in rows close together ; under bridges in clusters. In this way the moveable sand or untrustworthy material is traversed, and the cuna or rock bottom underneath is reached. The work is similar to that of sinking a shaft—a wall is built on a circular shoe, the inside excavated, and as the wall sinks down it is raised. There are instances in Europe, in Venice, where a wooden cooped well barrel was used, hooped by iron bands, and driven down by the weight of sandbags arranged round the top. There, as in India, when the well had gone down to the required depth, it was filled with stones or other material. If this fillings is not of itself cohesive there is danger that, when the wooden barrel staves in time decay, the enclosed substance may spread and the building come down. The cast iron cylinders filled with concrete of our time are a vast improvement of older methods, just like screw piles are much superior to driven ones, where for some reason or other they must stand in sand, like in the case of a lighthouse or landing pier, for the sake of economy. The methods by which cylinders can be sunk are manifold, and the choice depends on the nature of the soil and the depth to which they are to go down. In clay or stiff loam a bucket and chain or a grab and crane must be used. In sand or soft stuff suction pumps are preferable. The great difficulty is to keep the cylinders going down plumb, which is not always a very simple thing, especially where big stones, or more often old half-decayed logs, are met with. If they do not prevent the cylinder going down altogether until they are removed, they are apt to drive them sideways, like is sometimes the case in a bore hole. If very large cylinders or caissons must be put down to considerable depth, the soil is excavated through compressed air chambers, the so-called Potts system, being costly and rather risky. It is, on

the whole, a favourite device of Engineers that need not themselves work in the air chambers. If possible, it is always preferable to work in the open air. Even divers should be employed sparingly. Their work cannot always be depended upon, is slow, dear and not easily controlled. Any one who has ever been down in a driving dress will understand this well enough. Dressed in a suit of plate harness, and picking up pins out of the mud during a thick fog, would be something like a diver's work, and yet not half so tiring or dangerous.

A new kind of foundation is that of the sand pile. For this a hollow iron shaft is tipped at one end with a loose fitting pointed shoe, and driven down to the proper depth. Then the shaft is raised, and dry sand run down through it. This fills the space left by the shaft as it is raised, and the shoe abandoned. Very bad ground may be improved and rendered more compact this way, but under locks, sluices or weirs, it is not of much good.

Whether "pierre perdue" or rip-rap is a foundation depends on circumstances. In a breakwater it is part of the useful construction which begins at the bottom. The slopes under which a rip-rap mound will stand depend on the size of the stones, and on the exposure of the site. The smaller stones should be tipped in for the centre, the biggest on the outside. Mostly rip-rap mounds are used in the construction of breakwaters, but the building of a breakwater is another story, and lies outside our present subject. For quay walls in deep water such stone mounds will give good foundations, unless the bottom is too soft, and then the stones will go down to unknown depths and be lost, as was the case in New Orleans once, as also in Rotterdam.

In the construction of docks and navigation works it is a mistake to make them too permanent and costly. Nothing changes so continually as the needs of traffic by water, and the best policy is to provide what is needed at the moment at the least cost, cheap and nasty if you like, which in this case may be called business. Granite quay-walls, Gothic warehouses, Directors' names in golden letters on marble slabs, festive opening lunches with plenty of speeches and lots of champagne is art, and lies outside the scope of this paper.

It would be indiscreet to frivol away more time on this occasion, and therefore it is better to wind up with this remark, that the best foundation is the one which serves its end at the least cost.

THE PHOTOGRAPHIC CAMERA AS AN AID FOR EXPLORATION RECORD AND MEASUREMENT.

By J. Bridges Lee, M.A.

[Read before the Society on Thursday, 3rd December, 1903.]

Gradually but surely as education spreads people are coming to realise to an ever increasing extent the immense practical value of light printed records of facts. As might perhaps have been anticipated from *a priori* considerations, some of the leading astronomers of the world have been among the first to employ photography systematically and on a large scale for mapping the stars and for recording and exploring astronomical phenomena of many kinds.

In some departments of physical science also photography is now regarded by the most advanced and experienced workers as an indispensable aid for investigation, and the only agency in many cases by which reliable and readable records of important physical facts can be obtained. The use of photography among physicists and other classes of scientific workers is continually being extended to embrace new fields without deserting the older ones, so that it looks as if in due course of time corelated photographic records will be sought after and obtained of nearly every conceivable class of visible phenomenon and of many others not visible to our eyes but cognizable by photographic methods. Hitherto, no doubt (and probably also at present and for some time to come), a vast majority of people who make use of photography treat it as a sort of plaything with no higher object in view than to obtain some portraits of people and pretty or interesting impressions of views and things, but many people who take photography up as a hobby will probably desire to make progress in understanding, and to use their tools and materials intelligently, so as in time to be able to produce records which may be really useful and reliable and readable.

The aim of the author of this paper is to direct the attention of his readers to some of the simplest and most important principles which control photographic delineation, and must be

understood and applied whenever it is desired to use the photographs for getting exact information about the positions and proportions of the facts in nature which have been there portrayed.

All ordinary photographs are light printed records in monochrome on plane surfaces of some kind. The monochrome record may be conveniently conceived to be a surface area made up of an almost infinite number of tiny areas or spots or dots in close juxtaposition.

The different individual dots will be more or less dark or bright in proportion to the amount of light which has acted on them respectively. If they were all equally dark or equally bright there would be no discernable image. The differences or contrasts serve to define the picture. As a rule, the nature and amount of contrast between the tones of the image points bear an approximately definite ratio to the tones of the areas in nature to which these points correspond, and the positions are determined by definite simple principles which are not at all difficult to understand by anyone who correctly appreciates the nature of photographic projections.

The simplest possible type of camera is a dark covered in space with a small hole somewhere in one of its walls, through which alone light can enter the dark enclosure.

Now whatever photograhic image of any kind it may be possible to obtain within such a camera, it is evident that all the light which can operate to form the image must have come from the hole, so that the brightness of illumination of that hole must be equal at least to the sum total of all the brightness of all the parts of the whole image.

If the hole be regarded simply as a tiny window, it is evident that light rays traversing that window will constitute a double cone with common apex at the window. The portions of the cone on the two sides of the aperture (*i.e.*, inside and outside the window) will be similar in constitution, and the rays which travel from this window to form a photographic image are mere continuations along straight lines of the rays which have travelled from object points outside. The conception of a double cone of light rays, one half of which is completely filled with light rays travelling in straight lines from object points outside the camera towards a single point of entrance, and the other half filled with the same rays travelling straight along the same directions by which they reached the window, will conduce very much towards a clear perception of the relations which an ordinary photographic image bears towards objects photographed.

It is plain that the position of the apex of the double cone is all important, and that it dominates every possible image which may be formed inside the camera. That point may be called the station point, and it should be noted and always remembered that it lies in the straight course of every direct ray of light which

goes to form an image. Some further generalisations follow at once on this conception of the double cone. For example, since the two parts are similarly constituted it is evident that parallel sections of the cone on either side of the apex or at any distance from it will be similar in all respects as regards the relative positions of the points of light and shade which constitute an image or denote the form of an object. The areas over which images will be spread will vary directly as the square of the distance from the apex, and the brightness will vary inversely as the areas.

The exact similarity of parallel images in all relative proportions, and the simple definite numerical laws which govern their actual dimensions, are of great importance in practical metrophotography. By making appropriate changes in the position of the plane of projection (the image plane) it is possible in many cases to explore the directions and dimensions of object lines and planes with a camera under command, and thus to gather a lot of information in a short time about the forms and dimensions of objects.

For most ordinary purposes, when photographic records are desired, it is best to employ only certain definite plane sections of the cone and to adhere to them closely.

Exceptional sections, whenever they are used, should have their elements of deviation noted, so that, if necessary, they can be reduced to standard planes by projection or computation.

For nearly all ordinary terrestrial objects a vertical picture plane is best, and it is generally best also to have the vertical picture plane so placed that the point where the axis meets the picture plane may be at or near to the middle of the picture.

The perpendicularity of all perspective photographic projections will tend on balance towards the greatest number of the most natural looking pictures, and will secure vertical images for all vertical lines wherever they may appear in the field of view.

It will also secure exact copies without any distortion of any shape whenever those lines lie in vertical planes, which are also parallel to the picture plane. The condition of centrality is of much less importance, and in many cases it is expedient to depart from it, but in such cases the position of the centre (*i.e.*, where the perpendicular from the station meets the picture plane) must be known and marked or indicated in some way on the picture.

If the exact length of that perpendicular (the station distance or focal length) be known, then it is clear that a single photograph taken under these conditions yields all necessary information for determining any number of direction lines from the station to any object points whose images can be recognised in the photograph.

This generalisation then should be clearly perceived and remembered that *a photograph is a light printed record of the*

ends of straight direction lines from object points through the station point.

Any desired number of these directions can be ascertained from the investigation of a plane photograph, if we are in possession of the necessary information as above indicated.

In order to make use of these direction lines for practical topographical investigation, and for making maps, it is generally necessary, and nearly always best, to project them upon a horizontal plane, when they become rays of horizontal direction precisely similar in direction to the rays ruled on a plane table by alidades leading from a station point. The intersections of such projected rays from two or more stations suitably situated will suffice to fix positions on a ground plan.

The rules relating to choice of suitable stations, and for obtaining well-conditioned triangles, and for checking and controlling results, are the same as for all ordinary methods of survey work.

Any horizontal plane at any altitude will suffice as a ground plan for a map, but for purposes of analysis and for the better understanding and investigation of photographic records it is necessary to be certain about the trace of the horizon plane which contains the station point and the perspective centre of the picture. The projection of that plane on the picture plane is a horizontal straight line through the centre.

It is also necessary to be sure of the trace of the principal vertical plane, which will be a straight line through the centre perpendicular to the horizon line.

By these three planes intersecting at right angles all space inside and outside the camera may be considered to be quartered, and the relative positions of any visible points in space may be ascertained by reference to the intersections of those planes as co-ordinate axes. When photographs are taken with the traces of the principal horizontal and vertical planes marked upon them, then if the objects were sufficiently near to the apex when they were photographed, and the distance line for the picture sufficiently great, it would be easy to apply to those photographs the ordinary methods of interpretation taught in text books on perspective, but a very little observation and consideration will suffice to show that most photographs are too small to be conveniently measured as perspective drawings.

In order to obtain some clear conception of the possibilities and limitations of a camera for purposes of measurement it is instructive to make a few experimental measurements when the immense differences between the dimensions of the parts of the cone inside and outside the camera will be brought home to the understanding, and the experimentor will not expect too much in the way of precise measurement where the picture area is many hundreds or thousands or tens of thousands of times less than the

object area. Evidently slight errors in measurement will be large in effect in proportion to the smallness of the picture. On the other hand it has to be considered that photographs once obtained can be magnified many diameters without disturbing the proportions, and with the best modern optical and mechanical appliances a very high degree of accuracy can be obtained.

Really it is difficult to see any limit to the amount of ultimate precision of measurement which can be obtained by photographic means, only of course when short focus images are obtained, on the faces of which 1 in. linear measure may subtend 10 or 20 or more degrees of angle the same kind of precision cannot be obtained by direct reading as when the powerful telescope of a large theodolite is used for direct measurement of individual angles. Intelligently used with good appliances photography can be used for terrestrial and astronomical records and measurements of the greatest delicacy.

Hitherto the type of photographic apparatus under consideration has been the simplest conceivable, a mere pin-hole aperture in the wall of a dark chamber.

In the opinion of the author the principles and nearly all the most important problems of metrophotography can be studied to the best advantage with such simple apparatus.

An aperture in a thin opaque partition between two rooms, one very brilliantly lighted and the other absolutely dark, will suffice for many highly instructive experimental demonstrations in projection.

A tank of slightly milky water approached to the aperture in the dark room will serve to help to reveal the general constitution of the object cone, and sheets of opal glass and cardboard and paper, which can be bent or folded, will serve to illustrate the different images of the same objects obtainable with various sections of the cone.

The student is advised to commence to work with the simplest geometrical figures, especially straight lines, right angles, squares and circles on plane surfaces, which can be very strongly illuminated and placed at any required distance from the pin-hole, and the planes in any position in the light room. By moving the figured object planes and the receiving planes to different positions in turn on either side of the pin-hole much knowledge will be gained by the novice of some fundamental truths of radiant projection.

For after reference photographs can be obtained of the most important and instructive images by substituting sensitive dry plates for insensitive opals or cards. For investigating the constitution of the emergent cone, and the kinds of projection received on all sorts of surfaces, flat and curved, and at all sorts of angles of intersection, it is perfectly legitimate and expedient to make use of a great variety of surfaces moved from place to

place within the cone. By such means a good practical idea of the nature and possibilities of photographic projection and mensuration can be obtained, but for actual working purposes it will soon be found to be generally best to employ only vertical and horizontal sections for universal reference, as before indicated.

From the study of plane figures the student may next proceed to investigate the projections of cubes, spheres, cylinders, pyramids, etc., and thus acquire a fair working knowledge of perspective. When the pin-hole investigation have been completed a small Zjeiss Lens may be substituted.

This will be found to let through very much more light, and to yield very much brighter and more sharply defined images in focal planes perpendicular to the principal axis of the lens, and conjugate to the object planes, but if the lens has been correctly substituted for the pin-hole in position it will be found that the images obtained are always precisely similar in size and shape, and in all dimensions to the pin-hole images. Hence it is evident that photographs obtained by aid of a lens may be interpreted and measured as though they had been projected through a pin-hole. The advantages of the lens over the pin-hole for every-day practical work are so great that they are nearly always used, but a lens has also its limitations and disadvantages; for example, a lens is effective only at a definite focal distance, and the focal distance varies with the angular divergence of the rays, which have to be bent in their course to bring them to a focus, *i.e.*, with the distances of the objects. Also lenses are designed to yield true well defined images only in planes perpendicular to the principal axis, but in practice these limitations are not very irksome, nor are they so rigid as might be supposed without trial.

What is really wanted in the way of apparatus for practical work is a rigid camera of the simplest possible type, with suitable mechanical arrangements, to secure that there shall be no doubt or error about the exact position of the picture plane with reference to the station point, and no doubt about the position of the centre of each picture, and the traces of the principle horizontal and vertical planes through the centre. It is advantageous also, and often necessary to know, or to be able easily to ascertain the orientation of each view, and the position of the station point should be accurately known.

With these data and an ever-present clear mental conception of the nature of the photographic image, especially its geometric relation to a cone of rays, there should not be much risk of serious misinterpretation of an ordinary plane survey photograph. To use photography always to the best advantage for preparing complete sets of readable records, and to learn to read the records with ease and accuracy will require some careful attention and practice, but as with so many other branches of study and work, difficulties tend to vanish as they are tackled.

The great advantages of photographic records of topographical facts must be evident to any thoughtful student. No other records contain any approach to the same amount of accurate detailed topographical information as can be stored in and at leisure extracted from good survey pictures.

With really good reliable apparatus personal errors are to a large extent eliminated, and the instrumental errors may be reduced to a minimum, and such residual errors as there may be, will be, for the most part, constant and ascertainable. Perhaps in due course of time optical projection will come to be generally employed in the lecture rooms at our Universities and Colleges for teaching and demonstrating the principles of plane and solid geometry, especially the latter, which many people find so difficult to follow and understand when dealing only with hand-made drawings on plane surfaces. Let forms and figures projected on plane and other surfaces be studied as far as possible within the radiant cone to which they belong, when much that may have been thought to be puzzling and difficult will appear to be simple and easy of comprehension, and a general advance in those branches of knowledge which are concerned with the graphic representation of positions will follow.

SOME PROBLEMS IN CHAMBER BACTERIOLOGY.

By Samuel Rideal, D.Sc. Lond., F.S.I., F.I.C.

[Read before the Society on Thursday, January 7th, 1904.]

Last summer, when your Secretary asked me to read a paper before your Society, I thought that the compliment was implied that you, as a body of professional engineers, realised that bacteriology had modified the problems which you individually have to deal with in your several professions, and that it was on this subject that you wished me to speak. I take it that those of you engaged in problems of water supply and sewage disposal already realise the profound change which this modern science has made in your practice, and during the last year or two in connection with road sanitation the bacteriologist has also made contributions to our knowledge, which I venture to predict are destined very speedily to alter the aspect of our streets, and so to improve the conditions of hygiene in the large centres of modern civilisation.

The mechanical engineer, however, is interested in other subjects than these, and, with the architect, can be helpful in many ways in making the home more sanitary, and I thought in the summer that there were several aspects of this subject which might be usefully brought before the attention of your Society, in the hope that some members might devote attention to working out the details involved in successfully dealing with the problems of chamber bacteriology.

Unfortunately, my work has recently been directed into other channels, and I have been unable to prepare for this paper the material which I hoped to have been able to obtain. In many directions, however, there are indications that more thought and attention must be devoted to this particular subject, seeing that, after all, the greater portion of one's time is spent either in the dwelling-room or the bedroom, and that therefore the conditions of health are largely determined by the hygienic fitness of this environment. In all towns there are many houses which must always be considered infectious from notifiable disease, and are therefore directly under the control of the Medical Officer of the district. But the public has recently been warned as to the

dangers latent in certain districts, in certain streets, and in certain houses from previous contamination by phthisis or from cancer, so that it is gradually getting possible to map out in the cities isolated patches where these diseases may originate. It therefore becomes a question for the architect and engineer how to safeguard the people from the reproduction of similar danger spots, and in cases of restoration and renewal how to ensure the disappearance of all such sources of infection. The origin of the cancer house is more obscure than that of the tubercular house, but it cannot be doubted that to remedy the architectural defects of the latter, would give a clue to eliminating the former. Quite recently attention has also been drawn to phthisical infection which exists in the ordinary low-class public-house, where the dry sawdust floor acts as an undisinfected spittoon for the dangerous expectorations of a class of underfed alcoholic subjects particularly prone to this disease. It is easier to deal with a specific case of this character than with the general liability to infection of public buildings and vehicles, railway stations and carriages, the omnibus and the cab ; but in all cases one must look to the mechanical engineer and the architect for practical solution of the problem, and with the new materials which are continually being brought forward for constructional purposes it ought not to be difficult to design such a way that comfort and utility will be combined with artistic and hygienic surroundings.

In the question of the sanitation of rooms, for many years attention was almost solely directed to the subjects of ventilation and warming, and it was considered sufficient if an ample supply of oxygen was secured, and if the products of respiration and combustion were removed, while a suitable temperature was maintained. But this constant change of chamber atmosphere brings in immense numbers of dust particles, accompanied by micro-organisms, and I will later give you some particulars of their enumeration by various observers, and their nature as far as known.

Authorities now seem united in considering the admission of 30 cubic feet per minute for each person to be good ventilation, 1 cubic foot of gas burnt per hour being taken as equal to one person. On the other hand, there is a great divergence in practice as to the cubic capacity per person allowed in certain cases. Taking the extreme figures, the time required to bring the air to the standard of 12 parts CO_2 per 10,000,* if no fresh air be admitted, varies from eight minutes to seventy, showing that without ventilation this limit can be quickly exceeded in most rooms.

* The limit recommended in the report of the Departmental Committee on Ventilation, 1902, is 12 volumes CO_2 per 10,000, or, when gas or oil is used, 20 volumes.

But in practice the above is rendered inaccurate by ventilation through walls and crevices. The air of a room is ordinarily changed, by diffusion through the walls, about once every hour. With a good fire the change is still more rapid. Pettenkoffer found that with a difference of 40 deg. Fah. between the internal and external temperatures, the ventilation through the walls amounted to 7 cubic feet per hour for each square yard of wall surface.

But in judging of the healthiness of rooms, conclusions based on an arbitary standard of carbonic acid may be misleading. It is quite possible for the dust particles to include noxious germs, or even in their absence to predispose disease, as is very possibly the case with the pneumonia amongst the Thomas slag workers at Middlesbrough. A quiet room, settled and damped, might be used with impunity if the carbonic were much higher than the usually accepted limit. In my own experiments, persons have remained for some hours without sensible inconvenience in such a room when the carbonic acid has amounted to 60 volumes per 10,000.

With reference to the number of organisms in air, in outside air they are often less than 1 per litre; and in school-rooms as many as 600 per litre; but locality, age, cleanliness, altitude, light, and ventilation are among the factors which determine the average number that may be present.

The number of dust particles has been frequently estimated by Aitkin's Konimeter. The results obtained show that dust particles are present even at high altitudes—from about 200 in the purest air to 200,000 or upwards per c.c. They, of course, increase enormously when rooms are occupied. In foggy weather the number of particles also increase very rapidly. They are always far in excess of the number of micro-organisms, and are seldom less than 200 million, per litre.

Dust contains less of organic than mineral matter, and may weigh as much as 25 mgm. per *cubic metre* of air.

The number of organisms in the atmosphere is more in summer than in winter, but when a room has been closed and still for some time no bacteria are found in the air, though they at once appear in such a room after people have been walking about.

Ventilation currents have to be carefully considered, as the dust particles containing bacteria float in the air of a quiet room for several hours, and the slightest current will cause them to remain suspended for long periods. Minute drops of moisture may be transported by a current no stronger than 0·7 mm. pressure for a horizontal draught, or 0·1 mm. for an upward current, a fact of great importance in regard to the secretions of the mouth and nose. Agar plates become covered with colonies of bacteria at a distance of several yards from persons speaking loudly and energetically; coughing produces a still more rapid

and abundant colonisation, while plates show no growth when a person speaks low and quietly.

Rose estimated that 53 million bacteria were commonly present in the mouth, rising after lunch to 288 millions. Koeniger proved that bacteria (*B. prodigiosus*) were projected from the mouth of a speaker across a large room, and that they had entirely settled down after two or three hours, or in one hour if the room was free from draughts. He also found that the smaller species of bacteria were carried further than the larger.

Dr. Frankland found, at the South Kensington Museum, that the number of micro-organisms falling on a horizontal square foot of surface, just after rain, was 63 per minute; during a thick white fog it was 29 per minute! in a March wind it was as high as 1302.

In the recent report on the ventilation of the House of Commons, it is shown that in the open space surrounding the Houses of Parliament there are 4·2 organisms per litre, and one-third of this number at the top of the tower. In the debating chamber during a sitting only 5·8 per litre were found, whilst in the Committee and dining-rooms 32·3 per litre was the average.

If dust containing bacteria be deposited on a damp surface the organisms do not readily rise again. This accounts for their comparative absence in sewer air.

In sea air, experiments have shown that there are practically no bacteria present.

The actual detection of pathogenic organisms in the air has been accomplished in a number of cases. One of the most virulent organisms that has been proved capable of existing in the mouth and throat and of being transmitted by the air is the bacillus of leprosy.

The bacilli of influenza are well known to be present in the mouth and throat, and are of very small size.

The transmission of the tubercle bacillus by coughing, or even by the breath of consumptive patients, has been repeatedly established.

Dr. Germano proved the conveyance by dry dust of diseases, which he arranged in four groups:—(1) Typhoid, plague, cholera, influenza; (2) erysipelas, pneumonia, diphtheria; (3) cerebro-spinal meningitis; (4) anthrax.

It is fortunate that in ordinary respiration both dust and bacteria are arrested by the moist interior of the nose, and expelled by the ciliary membrane, in the mucus, to such an extent that quietly expired air is almost free from organisms, while few of those inhaled reach the lungs.

In addition to micro-organisms, air may contain fragments of carbon, of hairs, fibres of tissues, particles of starch, pollen granules, epithelium, &c. These can be removed by filtration

through cotton wool, also in great part, as we have seen, by passage over damp surfaces, or by subsidence. Cotton wool strainers are used at the Houses of Parliament; they can be made efficient, but they require considerable motive power to drive the air. Asbestos screens have the advantage that they can be renewed by burning; such screens have at present only a limited use. The ozonisation of the air after filtration, in order to destroy germs, has often been suggested, but the process has hitherto met with little success, partly from the irritant effects of the remaining ozone on the lungs.

Entering air can obviously be sterilised by heat, but heated channels are open to the following objections:—(*a*) If the air passes rapidly there is danger that the central parts of the current will pass without being sterlised on account of the bad conducting qualities of air; (*b*) the air so treated is unfit to breathe; (*c*) the coils if narrow become clogged and coated; (*d*) they are uncertain in action, depending on the working of the stove; (*e*) if made of fire-brick flues or fire-clay tubes, instead of iron, they are easily broken in stoking, stirring, or cleaning; (*f*) they have been known to cause fires by passing near woodwork.

The entering air can also be washed with water, with or without disinfectants. Numerous apparatus have been designed, with screens, bead tubes, plates, fans, or bubbling-through arrangements. Spray apparatus have also been used with good effect.

Although a very large number of inventions have been devoted to the purifying of air on its entrance, the principle is vitiated by two reasons apart from the expense:—

(1) The necessity for the frequent opening of doors, so that untreated air is constantly admitted.

(2) The fact that, as we have seen, the main part of the dust and organisms are derived from the persons present or brought in on their clothing, especially on their boots.

Everyone has noticed the clouds of unpleasant dust that are so frequently raised on wiping the feet on door mats, and it is a question how far this practice could be hygienically improved. Perforated india-rubber mats are less objectionable in this respect than the ordinary ones of fibre; they are more easily cleaned, and can with facility be kept slightly damp in dry weather. The deleterious nature of street dust is well known, and is one reason for the essential provision of a hall, to cut off direct communication from the outside. Doors opening directly into the living rooms from the street, as in poorer houses, or from a general open passage, as is found even in model artisans' dwellings, are a very objectionable feature of construction. Uncovering the feet instead of the head seems hygienically preferable. The snow-shoe or golosh is used far more generally on the Continent than in this country.

Like other sanitary precautions, the removal of the shoe with its possible pollution dates from very early times, and it is to be regretted that such custom has disappeared from modern life.

As dust cannot practically be excluded, the methods of its safe removal, and the avoidance of its accumulation, with its attendant organisms, demand attention.

We have already given instances of the adhesion of bacteria to moist surfaces, and this property points to the employing of damp cloths in the frequent cleansing of furniture, woodwork, and walls. Dry dusting is obviously only removing the evil from place to place. The familiar use of damp tea leaves, and the sprinkling of floors before sweeping are benefically directed to avoid this fault. There are several forms of rotary carpet sweepers that remove dust into a covered receptacle with little or no diffusion; these are much preferable to the ordinary broom. Of late years the removal of dust by machinery has received much attention, and a number of companies are working various methods. They may be divided into :—

(1) Fixed fans in the walls of a building, to help the ventilation; they can also be arranged as driving fans with air filters, warmers or moisteners, and this principle is largely used and very valuable in workshops. We have already referred to the limitation of its domestic application.

(2) The vacuum process. In this method accumulated dust is exhausted in the house itself by a portable machine, provided with a pair of vacuum pumps, actuated by an oil or electric motor, which serve to maintain a vacuum of several pounds to the square inch. Lengths of hose connected with this exhaust terminate in tubes, flattened out at the end into a long slit. These are passed over the surface to be cleaned and rapidly extract the dust.

(3) Compressed air. The vacuum process has the advantage that it can be applied to objects *in situ*, and it extracts all the loose or free dust that would be likely to be again raised and pass into the atmosphere. Compressed air which, it is stated, must be used at a pressure of not less than 70 lb. to the square inch, is comparable to beating in extracting the dust almost entirely.

But in all these processes, the removal of dust and bacteria avowedly is not thorough, and, from inquiries I have made among the makers, it appears that attention has not yet been given to sterilisation. It is said by several that articles that have been exposed to infection are not taken for cleaning. But how can this be certainly known? "Spring cleaning," without a further disinfection, is hygienically incomplete. Considering the ease and economy with which disinfection can now be accomplished by spray and by vapour or gas, I am of opinion that a house disinfection, room by room, should be ordinarily practised as a part of "spring cleaning."

Two or three points of construction must also be noticed.

Soil and foundations: Ground air.—Although a great improvement has taken place in artisans' dwellings, large numbers of houses, particularly in the suburbs of towns, have been erected, and are still in course of construction, which are unhealthy from various sanitary faults. To begin with, they have often been built on "made ground," the gravel and sand having been excavated, and the level made up with ashes or refuse, even though there are by-laws to the contrary. The concrete foundation is often unsound and made with unwashed road sweepings, and the floors are so pervious that ground air and emanations from the soil pervade all parts of the house.

It is well known that many pathogenic organisms survive and even multiply in soil. But if the base of the house be protected by a sound layer of tarred concrete or asphalt, it is not of so much importance on what soil it is constructed, so long as it is not one that is water-logged or infiltrated with fresh sewage.

I have often found that when the joists of the lower floor are too near the ground, the air-bricks are liable to become filled up with soil, and then "dry rot," produced by the spore-bearing organism *Merulius lachrymans*, frequently supervenes. If such an attack can be detected in time, the best remedy is to thoroughly spray twice with a hot 1 in 250 solution of corrosive sublimate, while the faults of the under ventilation must also be remedied.

Floors.—The Romans were in advance of us in constructing solid floors of incombustible material, with hypocaust furnaces for heating, an arrangement which caused an even distribution of warmth and ventilation, an exclusion of dust and the products of combustion, and tended greatly to cleanliness and healthy conditions. Floors of this kind could be thoroughly washed and rapidly dried, could be evenly cemented so as to be free from cracks and crevices where organisms could harbour, and could at any time be sterilised by clearing the rooms and increasing the heat. That such a system was suited to our climate is shown by its adoption in the Roman villa recently disinterred near Dartford, and in others in various parts of the country.

That the space now left between flow and ceiling is generally a receptacle for dirt, sawdust, shavings, &c., will be noticed by any one when floor boards are raised, and such a gathering, apart from fire dangers, is a breeding place for living things of all kinds. It is stated that in France it is common for the upper floors, even in small houses, to be laid solid with concrete and tiles. In the cheap construction of modern times, deal floors have frequently large spaces between the boards and under the wainscots, where dust penetrates. In many cases, owing to bad wood, the warping becomes so great that floors have to be re-laid. With the frequent scrubbing and washing necessitated by inferior flooring, the water runs into the seams, giving a dampness

which is eminently favourable to the development of bacteria. Fortunately, both soap and washing soda are to a certain extent disinfectant; but closely-laid polished floors, as for a long time usual on the Continent, are making headway in England, and should be universally adopted. Hard wood block floors are an excellent form. Beeswax and turpentine, used as a polish, are antiseptic and locally disinfectant.

Walls.—It has been well said that in small houses the aim should be to construct them in such a way as to leave the inmates the very minimum of attention required to keep the place clean, because in many cases that minimum will never be exceeded and often not reached. Therefore, carvings, deep mouldings, and all unnecessary projections, should be avoided as places for the accumulation of dust. Framed pictures are well known to harbour dirt and even vermin, and should be carefully attended to at intervals when they are taken down. The backs should be sprayed with dilute formalin, or with 1 per 1000 mercuric chloride, and allowed to dry before replacement.

Angles, particularly the one between floor and skirting, are places where bacteria are found in large numbers, therefore in some modern constructions especially in hospital wards, they are made rounded, so as to be easy to clean.

Walls were formerly porous, and, as we have seen, allow the air to penetrate at such a rate that the atmosphere of the room was usually changed by this means, once every hour. The air thus entering was filtered from bacteria, and this was so great an advantage that there is even now a divided opinion as to whether walls should be porous or not.

Modern decoration does away almost entirely with ventilation through walls, as varnished papers and wood dados are impervious. For cleaning walls, bread crumbs are much used on the Continent; they remove the dirt, and nearly all the bacteria.

Light is antagonistic to the great majority of bacteria, and direct sunlight is capable of rapidly killing them, therefore living rooms should be well lighted. In this respect many of the large blocks of model dwellings are not satisfactory.

GENERAL NOTES ON THE LONDON TRAFFIC PROBLEM.

By J. F. J. Reynolds, Assoc.M.Inst.C.E., Assoc.Inst.E.E.

[Read before the Society on Thursday, February 4th, 1904.]

The existence of this problem has been recognised for many years. As long ago as 1864 a Joint Committee of Parliament was appointed to consider the various railway schemes which were then being promoted. The recommendations of this Committee resulting in the construction of the Inner Circle and its extensions and junctions with most of the main lines. Since then several other inquiries have been held, and now the recently appointed Royal Commission on London Traffic is engaged in taking a voluminous amount of evidence, which it is to be hoped will lead to some practical recommendations and results.

The lately issued Report of the Departmental Committee of Highways, of their inquiry into Highway Authorities and Administration in England and Wales, toward the institution of which inquiry so much was done by the energetic Roads Improvement Association, has thrown much light on the question as affecting the whole country.

The financial loss which has been incurred by the lengthy delay in taking the matter in hand would be difficult to arrive at. Sir John Wolfe Barry has estimated that in the case of the four principal west-to-east routes alone, the annual loss to owners of vehicles and passengers, through loss of time due to congestion, amounts to over two millions sterling. It is, however, particularly fortunate that even at this late date there is a very good chance of something being done, for now that motor-propelled vehicles are coming into general use, it is pretty certain that before many years have passed they will form a very large portion, if not a majority, of the vehicular traffic, so that by an intelligent anticipation of events it may be possible to provide for the needs of the future, as well as to retrieve the errors of the past.

Let us first examine the existing state of affairs.

That the present means of traffic—at least, during certain hours of the day—are hopelessly congested is a self-evident fact. The resident in the suburbs finds it in his overcrowded morning and evening trains to the City. The resident in Westminster

finds it when he makes a journey to the City, especially if his destination lies at any distance from a railway station. The driver of a motor meets it when attempting to travel from, say, Charing Cross, anywhere in any eastward direction, the superior speed and power of his car being of little use to him against the mass of horsed vehicles.

The causes of congestion may be divided into two classes: first, those which can be remedied by further police regulations, or, if necessary, special legislation; and, second, those which come within the province of the engineer to remove by improved methods of construction and design.

To the first class belong: (1) slow vehicles which fail to keep next the kerb; (2) standing vehicles in narrow or congested roads; (3) the varying speed of vehicles, which makes "overtaking" difficult; (4) slow vehicles following too closely upon each other; (5) heavy slow vehicles following unsuitable routes at unsuitable hours; (6) vehicles going at an unduly slow pace, as, for example, "crawling" cabs.

All these causes could best be dealt with by the police. Special legislation, and even the appointment of a traffic regulating department, as suggested by Colonel Crompton may be necessary. The compulsory registration of all drivers, as is now required for motor men, might also tend to make them more careful.

To the second class, to which these notes more especially apply, belong the following:—(1) The concentration of traffic facilities at one point, as in the case of railway and tramway termini; (2) too few main arteries of traffic; (3) narrow roads; (4) traffic converging at points, and cross traffic; (5) the constant breaking up of street surfaces by statutory companies; (6) tramways in unsuitable roads.

Taking this list in order, we will as far as possible proceed to determine the extent and effect of these various causes.

(1) *The concentration of traffic facilities.*—There is at present no tramway nor high-level railway, and but few main roads, running directly through the central area of London; consequently every morning the incoming population is deposited at the various tramway and railway terminal points, and there left to distribute itself by walking, 'buses, cabs or underground railways. A comparatively small percentage of these passengers are deposited within walking distance of their respective destinations, a change of vehicles of some sort being usually necessary. Liverpool Street Station, and the tramway termini at Westminster Bridge, are typical cases of this form of congestion.

The total number of trains into the City between 6 a.m. and 10.30 a.m. is about 1320, a large number being overcrowded. Especially is this the case on certain lines, notably those from the east and north-east districts, where the growth of the suburban

population has already outgrown the existing facilities for passenger transport. The present population of greater London (the area within the jurisdiction of the Metropolitan and City Police) is about 6,000,000 ; the Royal Commission on the London Water Supply estimated that the population within the same area in 1931 would be from 8½ to 12 millions. An actual count of the number of persons entering the central area of London during these hours by train, tram, or bus, showed that over 300,000 entered from the north and nearly 200,000 from the south.

Another estimate gives the total number of persons entering and leaving the City daily as 1,200,000.

How serious this particular form of congestion may become, is well illustrated in the case of London Bridge. The number of pedestrians crossing the bridge daily is 120,000—or, say, equal to the population of Brighton. The footways are now being increased in width from 9 ft. to 15 ft. (the roadway remaining practically the same width as before) at an estimated cost of about £100,000, or an approximate cost of £150 per square yard.

(2) *The want of main arteries.*—There having been no pre-arranged scheme for the development of London, the result is that hardly a single road has anything like a clear run through, and certainly no road uniform in width and direction.

One cause of this has been the few bridges over the Thames ; between Kew Bridge and the Tower Bridge, a distance of 9½ miles, there are only fifteen bridges, while Paris has twenty-one bridges in seven miles.

The main roads of London are practically the same in width and direction as they were 100 years ago, while the population has increased six-fold.

There are a few cases of roads—such as the Edgware Road—running from or near the central area to the outskirts that are fairly straight, of fair uniform width, and good gradients ; but most of our main roads have a disappointing habit of losing themselves in a maze of narrow streets, or of making sharp double bends —an example being the Post Office end of Cheapside—or of contracting in width so as to become mere " bottle necks," as in the case of Grosvenor Place, which contracts in width from about 100 ft. to 50 ft. in a distance of 600 ft. The Charing Cross end of Whitehall in another case, contracting from 100 ft. to 48 ft. in a distance of 300 ft. ; in neither case is there any important branch road to reduce the through traffic.

There are also many cases of roads which are of good width, but comparatively short in length, which either stop entirely or are only continued by narrow streets—Portland Place and Queen's Gate, both over 100 ft. wide, being cases in point—the result is that very little long-distance traffic will make use of these roads.

The fact that so few main routes bear the same name throughout their length shows how they have grown from a mere string of short streets, each of which has been made by its own Authority for its own particular needs, often without reference to the requirements of through traffic.

The disinclination to carry roadways through the parks is another cause of the lack of through routes. This is partly due to the fact that London is none too well served in the way of open spaces, as the following table shows :—

Paris	has one acre to every		13	inhabitants.
Vienna	,,	,,	100	,,
Chicago	,,	,,	200	,,
Philadelphia	,,	,,	300	,,
Brooklyn	,,	,,	600	,,
Greater London	,,	,,	350	,,
Inner	,,	,,	1000	,,

Paris has one-third of its area devoted to roads and open spaces. The average cost of land for building purposes is greater than in London (the city excepted), the result being that it pays to erect handsome and lofty buildings. The density of population per acre is greater, but there is not so much overcrowding. In Berlin for the same reason there are practically no slums.

Many continental cities have had lines of fortifications to clear away within comparatively recent years, the area so cleared being used for boulevards and other improvements. There is no parallel to this in the case of London.

(3) *Narrow roads.*—Although Paris has little heavy traffic compared with London, there are within her 30 square miles of area 20 miles of boulevards having an average width of 140 ft., and in some cases 240 ft. Compare this with some of the principal London streets :—

Holborn	Averages 70 ft. wide for a distance of about four miles.
Oxford Street ...	
Bayswater Road ...	
Clerkenwell Road, &c.	Averages 60 ft. wide for a distance of about two miles.
Edgware Road ..	Averages 65 ft. wide for a distance of about three miles.

All of these are fairly good roads for London, and all of them are congested at certain points during the day.

Every cyclist knows that it is often quite safe to overtake a slow, heavy vehicle on the near side, between it and the kerb, instead of passing as he should do on the off side. This means that 4 ft. or 5 ft. of the road width are wasted, which frequently makes all the difference between leaving room for faster vehicles to overtake, and not, as obviously if a road be designed for, say,

four lines of traffic, the designer's intentions are upset. On the other hand, it must be admitted that the side of the road is the worst possible part for heavy traffic, for, owing to the cross fall, the traction effort is very much greater, especially if the road surface is at all greasy.

The average speed of vehicles is slow; the schedule rate of omnibuses is stated to be seven miles per hour; in many crowded streets it probably does not exceed four miles. There are about 1,500 omnibuses running on 160 routes, covering 242 miles of road within the County of London. The 'bus is, therefore, an important and fairly representative vehicle.

With the advent of the motor the average rate of speed will be increased, especially as in proportion to the area of roadway taken up the motor is more economical in carrying capacity, and owing to its superiority of control the headway at higher speeds need not be great. Colonel Crompton, in his paper read before the Engineering Section of the British Association, showed that by the use of motor vehicles with an increase of speed from 7 to 12 miles per hour it would be possible to treble the carrying capacity of a road.

At present, the fact that it is so often necessary for a fast vehicle to go over to the extreme right-hand side of the roadway in order to get room in which to overtake, tends to show that the capacity of many roadways is overtaxed.

Taking all these facts into consideration, we are forced to the conclusion that the traffic has outgrown the roads as they now are. Railways have found it necessary to widen, while but little has been done for the roads.

(4) *Converging and cross traffic.*—There are twenty-two points within the central area of London alone where there is congestion, chiefly owing to converging of crossing lines of traffic. The roadway between the Bank of England and the Mansion House is one of the worst cases. Here, in spite of special police regulations, there are eleven 'bus routes in one direction crossed by twenty-six in another, the total number of 'buses passing per day being nearly 700.

A recent report by the London County Council of the vehicular traffic at the junctions of Wellington Street with the Strand and of Southampton Row with Holborn, between 8 a.m. and 8 p.m., stated that :—

	Strand.	Holborn.
Daily number of stoppages by police	469	375
Duration of stoppages by police ..	7½ hrs.	5¼ hrs.
Average time of stoppage per hour..	40·9 min.	28·6 min.
Average daily number of vehicles ..	19,724	15,590

A detailed census, taken by the City of Westminster authorities, in Victoria Street near the Vauxhall Bridge Road, will be of special interest to the members of this Society :—

Census taken between 8 *a.m. and* 12 *midnight on May 5th last.*

Two-wheel carts	808
Two-wheel carriages	3,181
Four-wheel carts and wagons	2,092
Four-wheel carriages and cabs	1,753
'Buses	3,485
Motors and cycles	1,886
Total number of vehicles	13,205
Total number of foot passengers ...	48,710

This shows that the average headway during the whole period is rather less than 10 seconds, and is, of course, far less during the busy hours of the day, so that no new road with any large amount of traffic could be carried across Victoria Street without causing a serious blockage, as is now experienced in a small degree when a coal cart stops to deliver, and a slow-going vehicle has to crawl away from the kerb to overtake it.

(5) *The breaking-up of streets.*—There are forty-two different Authorities—not including Borough Councils—having power to break open streets in London. These include the various gas, water, hydraulic, electric light, telephone, and telegraph companies. The constant making of connections and repairs found necessary by the owners of pipes and mains, with the consequent breaking up of the streets, besides necessitating a partial or total diversion of traffic at the time, has a tendency to shorten the life of the road surface to a serious extent. There are about 5½ miles of pipe subways now in use, and more are being constructed in nearly all new streets.

The constant opening up of roadway and footpath boxes is another cause of interruption, which is aggravated by the apparent want of consideration shown by the owners. At one important corner a surface box was kept open from the middle of December, 1902, till July, 1903.

(6) *Tramways in unsuitable roads.*—As regards tramways, London is poorly served ; 115 miles have been constructed, of which the London County Council own 88. The following table gives the proportion of tramway mileage to population in several large provincial towns :—

London has	1	mile of tramway to every	30,000	inhabitants.	
Glasgow	,,	,,	,,	11,900	,,
Birmingham	,,	,,	,,	11,900	,,
Leeds	,,	,,	,,	9,500	,,
Liverpool	,,	,,	,,	8,400	,,
Sheffield	,,	,,	,,	7,300	,,
Manchester	,,	,,	,,	5,600	,,

With narrow streets, 'buses are preferable to tramcars, as they relieve the footways and can take their place fairly well with other vehicles, while tramcars take up more width, and owing to their want of flexibility, cannot adapt themselves to traffic requirements; but, on the other hand, in proportion to the area of road taken up, the electric car can carry more passengers. The introduction of a tramway into an already congested road only makes matters worse, as is shown by the fact that the average speed of a 'bus is greater than that of a tramcar in a crowded road; for this reason the 'bus is seldom entirely driven off its route by a tramway.

There are several cases in London where tramways have been laid along roads of unsuitable width; some cases are given in the following table:—

High Street, Shoreditch	50 ft. wide	all with a double line of tramways.
Old Kent Road	51 ft. ,,	
Newington Butts	40 ft. ,,	
Walworth Road	33 ft. ,,	

At one point in Brentford High Street the rail is only 2 ft. from the kerb, consequently it is not unusual for eight or ten cars to be "held up" by some temporary obstruction.

Centre pole columns and refuges are strongly objected to by many, as they restrict the width available for overtaking, especially if there is a greater volume of traffic in one direction than in the other, and they occupy the best part of the roadway for traffic purposes. It is, however, difficult to see how the use of these is to be avoided where there are tramways, unless the conduit system becomes universal.

With this outline of the state of affairs before us, we will proceed to consider what has, and is, being done to improve matters.

The question of passenger transport has long received the attention of capitalists. During the last twenty years £60,000,000 have been expended on the construction and widening of the various metropolitan and suburban railways. Tramways being in many cases impossible, the underground railway was for some years a distinctive feature of London. The early Metropolitan and Metropolitan District have been followed by the lately-opened tube railways, which have done much to benefit the long-distance passenger, and serve their several routes rapidly, and in most cases effectively. That they were urgently required was shown by their crowded state, during the busy hours, even a few weeks after they were opened, and temporarily, at least, they relieve the traffic on the routes served. The Central London Railway is said to have reduced the number of 'buses on the Bayswater Road from 1062 in 1895 to 920 in 1903, but the number appears to be creeping up again; also it must be noted that during the

busy hours this railway is even now overcrowded; as it is presumably worked at its maximum capacity, there is no provision for the growth of the population served by it and its tramway feeders.

In the case of the City and South London Railway the average overcrowding is 25 per cent. with a maximum of 60 per cent., and on the Waterloo and City Railway 19 per cent. and 52 per cent. respectively.

The tubes now being constructed will be exceedingly useful, especially those running north and south, but there is little doubt that they too will be overcrowded shortly after being opened. There are also several tube schemes which have been held over pending the Report of the Royal Commission now sitting; it does not seem possible for anything like all of them to be constructed; their united capital amounts to 38½ millions, and it has been stated that in order to pay 5 per cent. it would be necessary for them to carry nearly 600,000,000 passengers at 2d. The present tube lines carry less than 70,000,000 passengers between them, of which the Central London Railway carries more than half.

When considering any new lines it is important to remember that there are already nearly 600 miles of railways—including 13½ miles of tubes—within the area of Greater London.

Owing to the great cost of construction, tube railways can only pay on the most important routes, and the area to which they afford relief is narrow and confined to passenger-carrying vehicles. It therefore appears that tubes can only solve this problem to a very limited extent, and it is to the improvement of the roads and routes themselves that we must look to for the real solution.

Many excellent suggestions for improving the general plan of London have from time to time been made. Sir Christopher Wren's plan, made after the great fire of 1666, is well known; such an opportunity is not likely to occur again, and it seems a pity that this excellent scheme was not carried out.

No other man has come forward to do for London what Baron Haussman did for Paris, though several attempts have been made. In 1883 Mr. William Westgarth offered a prize of £1200 for the best essay on "The Reconstruction of Central London," and many excellent suggestions were contained in the Prize Essays. In 1893 Mr. Arthur Cawson, A.R.I.B.A., published a "A Comprehensive Scheme for Street Improvements in London," in which he advocated, amongst other suggestions, the opening up of the parks and areas owned by the Law Societies, as well as a complete scheme for the straightening out, linking up, and general improvement of the chief routes.

The Metropolitan Board of Works, followed by the London County Council, have carried out many important works,

including the Victoria and Chelsea Embankments, Battersea Bridge, and Westminster improvements, Holborn Viaduct, Northumberland and Rosebery Avenues, the Blackwall Tunnel, the Tower Bridge Approaches, and latterly the extension of the Mall to Trafalgar Square, and Kingsway with Aldwych, now approaching completion. Some of these works have proved very useful, while others have not been so fortunate. The Victoria Embankment, owing to its want of continuity and lack of building frontage, has hardly come up to expectations ; the Strand and Fleet Street, being the more direct route, continue to be used by all classes of traffic. The Kingsway, Aldwych, and Southampton Row improvements should do much for the north to south traffic, though the wisdom of making the west end of Aldwych discharge at what is already one of the most congested crossings in London—Wellington Street and Strand—is open to question. If Kingsway be continued south over the Strand and Thames, and thence through South London to, say, Croydon, a really useful through route would be made. Something on these lines has already been hinted at by the London County Council witnesses before the Royal Commission, and the approximate cost—including land for improvement—stated as being $1\frac{3}{4}$ millions per mile.

Road widenings and new roads have proved expensive, as is shown by the following table :—

Date.		Length. Furlongs.	Cost. £
1854	Cannon Street	$3\frac{1}{2}$	500,000
1870	Holborn Viaduct improvements	6	2,552,000
1871	Queen Victoria Street	5	1,076,000
1876	Northumberland Avenue	$1\frac{1}{2}$	711,000
1886	Shaftesbury Avenue	5	779,000

Northumberland Avenue is the only case of an improvement made within the last forty years that has resulted in a surplus profit.

At present unless a special Act is obtained, a street improvement can only be carried out under what is known as Michael Angelo Taylor's Act, in which case only such property as is actually required for the improvement may be purchased, the original owner having the right to retain the balance, and thus obtains the full benefit of the improvement, in addition to any profit made on the sale of a portion of his property.

The Holborn to Strand improvement has been carried out under a special Act, by which an area of land very much in excess of that actually required for the new roads has been compulsorily acquired, so that although the cost of the half mile of new roads has been about $4\frac{1}{2}$ millions, it is estimated that nearly 90 per cent. of this sum will be recovered by the re-sale of the improved properties. It is probable that—where possible—all

future improvement works will be carried out under similar powers.

Having regard to the way in which improvement works have been carried out in the past, and those in immediate contemplation, it is impossible not to be struck with the fact that a great want of continuity in the method of carrying them out has been shown. For instance, the *Morning Post* newspaper office has only been rebuilt a comparatively short time, and is now about to be pulled down to make room for Aldwych. The new building of the Institution of Civil Engineers is reported to be in the way of a contemplated improvement of Great George Street. A new stone-fronted building has just been finished on the north side of Piccadilly, near the Circus; if the improvement works be carried out here as proposed, within four or five years this building will have to come down, though possibly only a few yards of depth are required here. It has also been suggested that a certain amount of speculation in properties on the line of proposed improvements takes place which further increases the cost.

It therefore appears necessary that some new system of carrying out improvements should be devised, and it is to be hoped that when reporting to Parliament, the Royal Commission will recommend some satisfactory scheme. There are definite schemes on paper for the still unimproved portions of Paris, and at suitable times portions of them are taken in hand. Something on the same lines should be possible for London; it is not too late to form a complete scheme for both roads and railways.

The best methods of carrying out such a scheme as regards finance and administration hardly come within the province of the engineer to define. That it should be a department or sub-department of State appears necessary, though some of the details might safely be left to private enterprise. To this department should be left the preparation of a definite scheme under expert advice; the promotion of the necessary Bills; raising of loans; negotiations for properties; construction of the works, and finally the re-sale and administration of the improved lands, and possibly the granting of various concessions. If full advantage were taken of the termination of leases, destructive fires, properties coming into the market, the clearing of insanitary areas, &c., along the site of the scheme, it should be possible, with careful finance, to effect many vast improvements at a not excessive cost to the ratepayers.

For such a general scheme to be thoroughly satisfactory it does not appear that any system of improving the existing thoroughfares will be sufficient, while the expense would be practically prohibitive. No road widening could ever be made to pay for itself within the limits of the City; it has been stated that Lombard Street alone has been valued, for expropriation purposes, at one hundred millions. The projecting cellars which exist in

nearly every street are another source of difficulty and expense, also the great number of mains and wires which would have to be shifted were any form of subway to be provided. In the light of past experience it appears to be cheaper in the end to carry out work on the lines of the Holborn to Strand improvement than on the lines of the Strand widening.

There are several points in favour of an entirely new thoroughfare as compared with the widening of existing roads. For instance, special provision in the Act could be made as to traffic regulation; special sanitary by-laws, such as the compulsory washing down of pavements once a week, as in Brussels. Owners of mains and wires could be compelled to make use of, and pay rent for, subways. Regulations as to the height and character of buildings could be enforced. An entirely new and independent drainage system, uniformity of pavements, and improved methods of scavenging and cleaning the roadways by washing direct into gullies (it costs London over a million a year to clear away mud by the present methods) could be introduced.

In order that any system of new main thoroughfares should be satisfactory and efficient, they should start on one side of London, well beyond the present limit of building, be carried as near as may be practically possible to the City, and continued to the open country on the other side. It would not be possible, within the limits of this paper to even suggest the number or direction of such routes, but a few essential points may be noted.

In selecting a route, the starting-point should be at or near one of the main turnpike roads, such as the Bath or Great North Roads, well beyond the present contemplated limits of suburban dwellings—this in itself would at once afford much relief to many existing routes. The crossing of high-level railways should be avoided as much as possible, also running too closely parallel to existing main roads. The direction should be straight, and the width uniform throughout. Advantage should be taken of insanitary property. There does not appear to be any reason why squares and other small open spaces should be avoided; the new main thoroughfare would in itself be a most efficient open space or lung. Most London square gardens are a positive hindrance to traffic—as is exemplified by Hanover Square as compared with Sloane Square. A flat road is not necessary; an undulating section being preferable for drainage purposes, but the maximum gradient should not exceed 1 in 30 or 35 for any great distance. The width of land to be compulsorily acquired would vary in different districts, but the depth on each side should at least equal the width of the thoroughfare.

The determination of the width and cross section of such a main thoroughfare is an important and difficult matter, which is increased by the fact that the volume of traffic will necessarily vary, and that very nearly the maximum amount must be provided for.

Assuming that all classes of vehicles are allowed to use the thoroughfare, it is necessary to provide for standing, slow, and fast vehicles, at least one double line of tramway and for foot passengers. A width of 14 ft. for each footway should be sufficient, as it allows for a standing line opposite shops, &c., and for three moving lines in each direction.

As has already been pointed out, the side of a roadway is not the best place for heavy vehicles, therefore they should be allowed to occupy the second line of traffic, the first being reserved for standing vehicles. Two fast lines, for horse driven and motor vehicles and a line for overtaking, for which the tramway width should not be considered as generally available ; a tramcar service with a headway of about thirty seconds, to be satisfactory, must have as clear a track as possible.

We therefore have to allow for six traffic lines in each direction—viz., standing, slow, fast, motor, overtaking tramway, the first five lines requiring 8 ft. of width each, and the tramway 10 ft., making the half-roadway width 50 ft. Several objections to wide roads have been urged, among others the excessive crossfall, difficulty of foot passengers crossing, and unpopularity with shop owners. On the other hand, they are healthier, permit of high buildings being erected without interfering with light and air, and are certainly satisfactory from a traffic point of view. To meet the above objections, as far as possible, it is suggested that the roadway should be in halves, each half being used by traffic going in one direction ; thus by keeping each roadway width down to 50 ft., the crossfall would not be excessive. This would be preferable to having the fall from the sides to the centre, as suggested by Mr. Sennett ; a centre gutter would be strongly objected to by all users of rubber tyres. Refuges, which would also serve for tramway stations, should be provided, as they would at times be crowded with passengers, and in order to allow a safe distance between the tramway lines for vehicles crossing from side to side, a width of 12 ft. is suggested. Being frequent, they would form, practically, a non-continuous footpath, carrying the combined arc lamp and trolley wire standards. Crossings for vehicles between the sides of the roadway should be frequent, and space reserved for various other purposes, including :—Lavatories, entrance to subways, cab ranks and shelters, fire escapes, fire alarms, orderly bins, sand bins, water troughs, ambulance stations, police stations, telephone stations, messenger stations, fire stations. These are all requirements of a roadway, and space for them is often difficult to find.

These dimensions give a total width between the building lines of 140 ft. Allowing a headway of ten seconds on all moving lines, the capacity would be equal to 1,080 vehicles per hour in each direction, exclusive of tramcars, without overcrowding. Or, in other words, equal to the combined capacity of Piccadilly and

the Strand. If this were not found to be sufficient within the central area, a relief or "by-pass" road on the lines suggested by Mr. W. Rees Jeffreys could be constructed, say about the four-mile circle; through motors would readily travel the few extra miles for the sake of a clear road.

Duplicate pipe subways under each footpath would simplify the house connections, and a centre subway on the line of refuges would be convenient for the lighting and tramway mains.

It is obvious that it would not be possible to allow any other considerable line of traffic to cross the main thoroughfare, as a stoppage for even a minute would be a serious matter, especially for the tramway service. At the same time, suitable means must be provided for enabling traffic to pass to and from the main thoroughfare to existing streets as readily as possible. For this purpose it would be necessary to carry at least a portion of the main thoroughfare over existing roads, on the lines of a suggestion made some years ago by Sir John Wolfe Barry for the Wellington Street—Strand and other crossings. Fig. 1 shows how this bridge could be combined with a connection to an existing road; the bridge carrying the tramways, six lines of vehicles and two 6 ft. footways is approached by gradients of 1 in 40, while the side portions, which consist of the two 14 ft. footways and two 18 ft. approach roads each side, cross the existing road on the level. By increasing the width of the main thoroughfare to 180 ft. for the length of the approach roads, it would be possible to carry the whole of the normal main thoroughfare traffic over the existing roadway, and still allow reasonable width for the approach roads. Where several existing roads have to be crossed close together, the main thoroughfare would be carried over bodily, suitable approach roads being taken off at right angles. Another suggestion is shown in Fig. 2, in which case the existing road is carried over the main thoroughfare, curved approach roads springing from each end of the incline. The four three-cornered block would be valuable properties. This form of crossing might be adopted for existing roads without widening.

In the process of constructing such a main thoroughfare as has been here outlined, it would be necessary to displace a large number of workpeople, who would have to be rehoused as far out towards the country as possible. To compensate for this, and to further increase the usefulness of the main thoroughfare, a system of rapid transit must be provided. A surface railway being out of the question, there remain three known systems that could be adopted, viz., tube, shallow subway, and elevated railways.

The prospect of a 12-mile journey in a tube twice a day is hardly pleasing. Further, as 13 ft. 6 in. is now considered to be the minimum diameter allowable, and the cost of construction in the water-bearing strata, such as that in certain parts of the

neighbourhood of London, is higher than through clay, it is probable that the cost would at least average £500,000 per mile, including equipment; while the necessity for providing lifts and lighting trains and tunnels throughout the day would make the working expenses heavy.

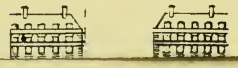
A shallow subway would hardly be much pleasanter to travel in than a tube, and with both systems there is the difficulty of getting passengers clear of a train in the event of a fire, such as that experienced on the Paris Metropolitan a short time ago. In the case of a subway costly pipe and sewer diversions would be necessary when crossing most existing roads, so that the ultimate cost per mile would be little less than that for a tube, and while lifts would not be required, there would still be the constant charge for lighting.

An elevated railway such as that of New York or Liverpool, or even the improved Berlin system, is never likely to find favour in London. A suspended railway such as has been successfully running for the last few years between Barmen and Elberfeld in Germany, and is now proposed for the cities of Berlin and Hamburg, is free from most of the objections to other types of elevated railways. As no solid deck is required for the superstructure, there is a minimum interference to light and air; travelling is pleasant; there is no cost of lighting during daylight hours, and with automatic signalling the traffic could be carried on independently of fog. In the possible event of fire resulting from a short-circuit or other causes, the worst that can happen is that the train would be brought to a standstill. This system being a true mono-rail, it has great flexibility as to curves; and, finally the cost is only from one-third to one-fifth that of a tube. Such a railway could be carried down the centre of the suggested main thoroughfare, with arched supports every 120 ft., space being left for either trams or motor cars to pass along underneath, or centre supports placed on the proposed refuges could be used.

In any system of rapid transit the stations should not be less than one mile apart, to enable a good average rate of speed to be obtained, the intermediate distances being served by the tramways.

THE LONDON TRAFFIC PROBLEM

— SUGGESTED METHOD OF CARRYING A NEW MAIN THOROUGHFARE ACROSS AN EXISTING ROAD —



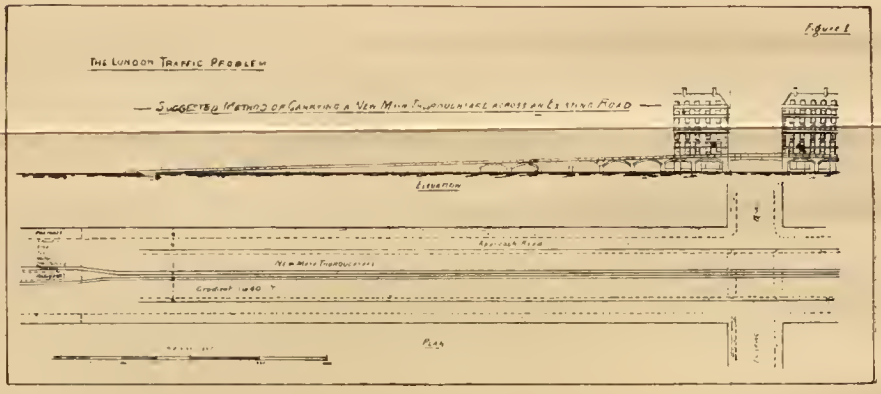


Figure 1
THE LONDON TRAFFIC PROBLEM
— SUGGESTED METHOD OF CARRYING A NEW MAIN THOROUGHFARE ACROSS AN EXISTING ROAD —
ELEVATION
PLAN

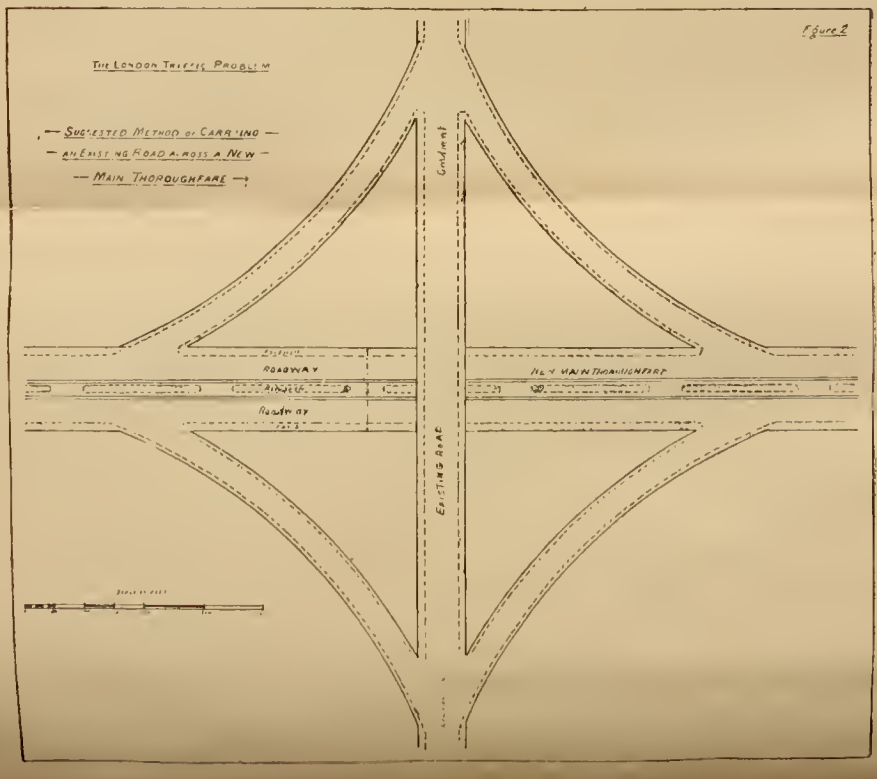


Figure 2
THE LONDON TRAFFIC PROBLEM
— SUGGESTED METHOD OF CARRYING —
— AN EXISTING ROAD ACROSS A NEW —
— MAIN THOROUGHFARE —
EXISTING ROADWAY
FOOTWAY
FOOTWAY
EXISTING ROAD
NEW MAIN THOROUGHFARE

DYNAMO AND MOTOR TESTING.

By Professor C. F. Smith, Wh.Sc., A.M.I.C.E., A.M.I.E.E.

[Read before the Society, on March 3rd, 1904.]

Generally speaking the commercial tests carried out on dynamos and motors may be divided according to their purpose into three classes.

1. The maker's test at the works on completion of each machine.

2. The purchaser's test, usually made after fixing in position.

3. More complete tests and measurements made by manufacturers upon a new line of machines or carried out in order to investigate some special feature or modification of design, or to ascertain the suitability of a machine for a particular purpose.

Equipment of Test House.—A number of motors supplied with current from starting boards provided with speed regulating resistances provide the power required to drive the dynamos to be tested. Further switch-boards with measuring instruments and connections to the load resistances, which must be capable of a variety of connections, enable the generators to be loaded during the test.

For supplying the various voltages that may be required for testing motors, motor generators taking current from the supply mains and capable of giving out voltages varying over considerable ranges by means of shunt regulation are required.

For testing combined sets a supply of steam provided with a separator for ensuring dryness is necessary If complete tests of steam consumption are to be made, a condenser and water measuring tank must be added.

Manufacturer's Tests. — Before the machine is run, the resistance of the armature windings is carefully measured and recorded. Also the insulation between the windings and the frame is tested by the application of a voltage higher than that of the circuit upon which the machine is intended to work.

The armature resistance in the case of small machines in which the resistance is not very low is most conveniently measured by the drop of potential method. In that case a current is sent through a low standard resistance and the armature connected in series. The drop of voltage in the

armature and in the stand resistance are then compared by connecting the leads from a reflecting galvanometer to the terminals of each in turn. The resistances are then proportional to the reading of the galvanometer.

For large armatures in which the resistance is less than $^1/_{1000}$ ohm, it becomes necessary to use a double bridge method in which the drop of potential in the armature and standard resistance are compared by means of a bridge consisting of four resistances, instead of producing a direct deflection of the galvanometer. The final adjustment of the resistances is obtained when the galvanometer remains at zero on depressing the galvanometer key, so that this is a null method, and the galvanometer is used under the most sensitive conditions.

In addition to the measurement of the total armature resistance from brush to brush, it is usual to measure the resistance between every adjacent pair of commutator segments in order to detect any lack of symmetry due to faulty connections by the armature winder, defective joints, etc.

The measurement of the field resistance is usually made at the end of a continued run when the windings are heated to the normal running temperature.

The resistance of the shunt field winding of a shunt or compound dynamo or motor may be measured with an ordinary Wheatstone's bridge, but it is usually more convenient to calculate the resistance from simultaneous readings of current and voltage applied to the winding.

The increase in resistance of the field windings when heated by the exciting current forms the bestbasis for determining their rise of temperature.

The resistance of a copper conductor increases by ·428 per cent. of its value for each degree cent. increase in its temperature. Consequently in order to find the mean temperature of the coils after they have become heated, the following formula may be employed :—

$$t_c = \frac{r_2 - r_1}{r_1} \times \frac{100}{\cdot 428}$$

$$t_f = \frac{r_2 - r_1}{r_1} \times \frac{100}{\cdot 238}$$

where t_c = rise in temperature in degrees Centigrade,

t_f = rise in temperature in degrees Fahrenheit,

r_1 = resistance when cold,

r_2 = resistance when hot.

If the current supplied to the winding for this measurement is its normal working current, or if the voltage applied at the terminals is the normal working voltage, a series of values of the

resistance may be obtained as the winding gradually becomes heated by the current, and its resistance increases in consequence.

Fig. 1 gives a curve obtained in this manner. The shunt windings of a small dynamo were connected to the 100 volt mains, and readings of the current flowing through the coils were taken every 10 minutes. The voltage at the terminals of the windings was also observed, and the resistance of the windings calculated. It will be seen that the resistance increased rapidly at first and afterwards more slowly as it approximated to its final value. After about $1\frac{1}{2}$ hours the final resistance of 141·8 ohms was practically reached.

The upper curve on fig. 2 shows graphically the result of a determination of the temperature rise in the shunt windings of a small 2-pole motor made in this way.

The lower curves on the same figure show simultaneous readings taken with mercury thermometers placed with their bulbs in contact with the windings, and well covered in with cotton wool to prevent radiation of heat as far as possible. The thermometer, whose readings are shown by the lowest curve, was placed on the outside by one of the magnet limbs. The curve gives the readings of thermometer placed between the magnet limbs against the inner surface of one limb.

The final readings of the thermometer placed against the outside of the windings are seen to be 5 deg. C. below the average temperature of the coils, as measured by the increase in their resistance.

If the average temperature is assumed to be the mean between the hottest and coolest layers, the hottest layer would be about 10 deg. above the temperature indicated on a temperature applied to the outside of the coil. The depth of winding in this case was only $\frac{3}{4}$ in.

The readings here referred to were taken with the armature stationary. In revolving, the armature fans the coils and cools the outer layers, so that the temperature difference would be much greater with the machine at work.

It will be seen that the final readings of the thermometers differed by nearly 21 deg. C. A little carelessness in wrapping up the thermometer bulb during a test may cause a still greater error than would be incurred by taking either of the curves in fig. 2 as giving the true temperature of the coils.

It should be remembered that the actual temperature of the inner layers of the windings must be higher than the temperature indicated by any of the curves, since even the highest curve on fig. 2 only gives the *average* temperature of all the windings.

The hottest layer is found not to be the layer next the magnet limb, since the iron of the magnet cools the layers next to it. It is usually about one-quarter of the depth of the winding from the inner layer.

In order to illustrate further the errors to which observations by means of mercury thermometers are liable, the curves on fig. 3 are given. They indicate the readings simultaneously taken on two thermometers placed respectively between the limbs and on the outer side of one limb of a small 2-pole motor. The thermometers were placed closely against a wrapping of thin fibre with which the windings were protected. The magnets being rather close together, the inner thermometer was in a very well-protected position and received heat from both magnet limbs. Both thermometer bulbs were covered with cotton wool, and a constant potential was applied to the magnet windings.

In order to investigate the temperature of the inner layers, a spiral of fine platinum wire wound on to a flat strip of fibre or mica, and carefully covered with silk ribbon, may be used. The flat strip can be inserted between the windings and the iron core, or may be laid between the layers of wire during the winding. By measuring the increase in resistance of the platinum coil its rise in temperature can be calculated without removing the coil. A coil of this kind measuring about $\frac{1}{2}$ in. by 3 in., having about 50 turns of bare platinum wire, and a resistance of 10 ohms wound on to a thin strip of mica provided with notches like saw teeth in the edge, to keep the windings separated, and well covered with silk ribbon, answers the purpose well.

Thermal junctions applied in a similar way have also been made to give good results. If a mercury thermometer is used, the bulb should be wrapped round with tin foil to distribute the heat uniformly to all parts of the bulb.

Mr. E. Brown had made some experiments on the internal temperature of dynamo field coils,* and found that in the case of the 2-pole dynamo which he experimented upon, the temperature rise of the external layers was 29 deg. C., the average rise through the depth of the winding was 50 deg. C., and the maximum rise was about 60 deg. C. Thus, the maximum rise in the interior of the foil was more than double the increase which would have been registered by a thermometer applied at the surface of the coil in the usual way. There was, in fact, quite as large a difference of temperature between the hottest part of the winding and the surface of the coil as there was between the surface of the coil and the air of the room where the test was conducted. The results were obtained with the dynamo running.

The permissible rise in temperature during the trial run as well as the methods of determining the rise vary in different factories, and until the report of the Engineering Standards Committee is issued it is difficult to compare the capacities and output of machines by different makers from the nominal output.

* Proceedings of the Institution of Electrical Engineers, Vol. XXX., p. 1159.

The Verband Deutschen Elektrotechniker have issued the following standard methods of testing and permissible rises of temperature :—

Rating of Machines.—These ratings are distinguished—

(*a*) For intermittent working, in which the machine has alternate short periods of work and rest, (*e.g.*, motors for cranes, lifts, tramways, etc.)

(*b*) For short periods working, in which the working period is less than that required to raise the temperature of the machine to its final value and the period of rest is long enough for the machine to fall practically to the atmospheric temperature.

(*c*) For continuous working in which the working period is long enough for the machine to reach its final temperature.

(*a*) The output of a machine for intermittent working is the output which it will give continuously for one hour without exceeding the permissible temperature rise, and should be denominated the output for intermittent working.

(*b*) The output for short period working is the output which the machine will give during the contemplated working period without exceeding the permissible temperature rise. The output must then be given together with the allowable duration.

(*c*) When rated for continuous working, the machine must be capable of giving out the stated output for an indefinite period without the permissible temperature rise being exceeded.

Permissible Temperature Increase.—The temperature rise is to be determined—

(*a*) In the case of machines for intermittent working after a continuous run of 1 hour.

(*b*) In the case of short period working machines after the application of full load for the duration of the contemplated period.

(*c*) With the machine for continuous working after the application of full load for 10 hours, or on attaining the final temperature if this is reached in less than 10 hours.

The temperature of all rotating parts is to be measured by means of a mercury thermometer, precautions being taken to make good contact with the part of which the temperature is being measured, and also to prevent loss of heat.

The temperature increase of all stationary windings is to be calculated from the increase in resistance.

Under ordinary circumstances and when the temperature of the air does not exceed 35 deg. C., the following are the maximum permissible increases.

(*a*) Insulated conductors with cotton insulation ..50 deg. C.
Insulated conductors with paper insulation .. 60 deg. C.
Insulated conductors with insulation of mica, asbestos, or preparations containing these...80 deg. C.

10 per cent. higher values may be taken for stationary conductors.

(*b*) For commutators ... ...60 deg. C.

(*c*) Iron parts in which conductors are embedded rise of temperature as under (*a*) according to nature of insulation.

In the case of tramway motors the rise of temperature as measured in the test house may be 20 deg. C. higher than the values given above on account of the cooling effect of the air when the machines are run under working conditions.*

Method of Absorbing Power.—In the case of small dynamos the output is absorbed in resistances, which usually take the form of frames of iron wire coils. Light wooden frames with ordinary galvanised wire netting stretched upon them make a very inexpensive but rather bulky form of resistance. A water tank filled with a solution of common salt or sodium hydrate may be used as a load resistance.

In test houses specially equipped for the frequent testing of large generators, arrangements are always made for usefully employing the current generated whenever possible. Mention will be made of the methods of testing in which a pair of machines are coupled and tested together. A similar arrangement may be made so that the power generated by a dynamo under test is supplied to the motor which drives the dynamo. In order that this may be directly possible, the motor must be wound for approximately the same voltage as the dynamo under test, and the extra power is supplied from an additional machine.

Suppose that a machine which has its field windings excited in a definite direction has its armature connected to a source of electrical power. If left free to rotate, the armature will revolve, taking current from the mains, and the machine will operate as a motor, at a definite speed depending on the voltage of the line and the strength of its field. If now the armature be driven at a slightly higher speed by external means, sufficient voltage will be generated in the armature to diminish the current taken from the supply. The machine is said to run at the critical speed

* Figs. 4 and 5 show the two most important curves to be obtained in testing a new dynamo, viz., the no-load and full-load magnetisation curves. Their features were briefly discussed by the Author.

when the voltage generated in the armature exactly equals the applied voltage of the mains. When the rate of rotation is made to exceed the critical speed, the machine becomes a generator and supplies current to the line. Thus a shunt or separately excited machine running at less than its critical speed operates as a motor; when its speed is higher than the critical value it operates as a generator. Since the critical speed is proportional to the line voltage, divided by the strength of the field, it is possible for two similar machines running at the same speed to act as motor and generator respectively if the field of one is made to be weaker than the other. Under these conditions, the current of the generator may be employed in driving the motor, and the motor may consequently derive most of the power it requires from the generator which it drives. By increasing the difference in excitation of the two machines the difference of their critical speeds is also increased, and the power developed in the armatures of both machines becomes greater. In this way large machines when tested in couples only require the supply of the small amount of power necessary to make up the losses occurring in them even when tested upon full load. This method of procedure forms a foundation of many of the methods of testing employed. Only a few typical arrangements can be enumerated.

In cases where dynamos have to be tested for very large outputs it becomes important to make use of the power generated when such machines are undergoing their trial run. In such cases the arrangements to be adopted are necessarily largely governed by the special equipment of the test house and the machines available.

If the machine is to be tested under load while driven by its own engine, the usual plan is to absorb the power generated in resistances, since electrical power is not taken from the mains, and it is consequently not of the same importance to supply power to them as it is when the use of the current is to be made good.

If the generator voltage happens to be that of the mains, the current may be supplied to the circuit in order to relieve the station generators. In this case considerable caution must be used to avoid disturbing the line voltage, and the machine under test should be protected by a reverse current automatic cut-out.

In other cases it may sometimes be worth while to drive a motor generator by means of the current generated. The motor is then driven by the current generated during the test, and being coupled to a generator whose voltage is that of the line, the power generated may be supplied to the installation as before. If the dynamo is to be motor-driven during the test, it is often possible to adopt a similar method to that employed in the Hopkinson method of testing dynamos.

The illustrations show two methods in which this may be done.

In the first, fig. 6, a supply of equal voltage to that of the test machine is available. The motor is then directly connected to the terminals of the machine which it drives. The additional power required to supply the losses occurring in the two machines is derived as shown from the test house mains.

This is the method most frequently used when several machines of the same type are being turned out, and on account of its simplicity is adopted in the case of machines down to quite small sizes. In fig. 7 is shown the case of two machines of equal voltage being electrically and mechanically coupled and driven by an auxiliary motor taking power from the mains. The two machines may be either, both machines to be tested, or one of them may be only introduced in order to economise power by assisting to drive the test machine by means of the power generated by it.

The machines usually available in the test house cover a considerable range of voltages, since the voltage of a machine may be made to vary considerably for such purposes by choosing a suitable diameter of pulley. The voltage then varies directly as the speed of the motor, and the excitation may also be varied over a wide range for temporary work of this nature. Fig. 8 shows three machines which are all mechanically driven by each other through belt gearing.

The two machines G and M are a generator under test and a motor driven direct from the power mains respectively. The third machine is a booster inserted in the circuit between the generator and motor in order to adjust the generator voltage to the value required by the motor.

The amount by which the booster alters the generator voltage is adjusted by a rheostat in the booster field, and the sense in which the voltage is altered is determined by the direction of the exciting current. If the generator gives a voltage lower than that of the motor and supply mains, the booster is driven by the motor and adds its voltage to that of the generator, so that the current generated becomes effective in driving the motor. If, on the other hand, the generator volts are higher than those of the supply, the booster is made to act negatively, and to oppose the E.M.F. of the generator, so that again the current supplied to the motor is at the correct voltage. In this case the booster acts as a motor and will assist mechanically in driving the motor M.

Indirect Methods of Measuring Efficiency.—Since the power supplied to a dynamo is the sum of its useful output and the power lost in the dynamo, it is sufficient, in order to determine the efficiency, to make measurements of the output and of the lost power.

Efficiency per cent.

$$= \frac{\text{power given out}}{\text{power given out} + \text{power lost}} \times 100.$$

Efficiency Test of Two Coupled Dynamos.—For this method of testing two similar machines are necessary. At a manufacturer's works this is usually no serious disadvantage, since it is usual to build more than one machine at once of a given type and size, or a machine of approximately the same size as the one to be tested can usually be employed temporarily.

The shafts of the two machines are coupled together. This is usually done by standing the machines in line with one another and joining the shafts by a flanged coupling, or preferably by a flexible coupling. Sometimes the machines are placed at some distance apart, and one drives the other by a belt passing over equal sized pulleys on the shafts of the two machines. In this case an additional loss of power is introduced in the friction due to the belt, also the speed of the driving machine will be slightly higher than that of the driven one, owing to the slip of the belt. The terminals of one machine are connected to those of the other.

One machine is then supplied with current, and made to act as a motor and drive the other. The current generated by the second machine is supplied to the first. In this way one machine is made to act as a generator and produce most of the current required for driving the other, which acts as a motor. The motor in turn supplies most of the power necessary to drive the generator.

Since there will be losses in both machines, a small amount of power from an external source must be supplied to keep the machines running. This power will only be the amount required to make up for the losses occurring in the two machines. The machines can in this way be made to work at full load, while only requiring a relatively small supply of power from an external source to enable the test to be carried out.

Large machines can in this way be tested at all loads without taking heavy currents from the supply mains. This is often a matter of great importance. The losses occurring in the two machines at any load are equal to the power supplied to them in order to keep them running at this load.

Two Coupled Machines Connected in Parallel.—Various methods of supplying the additional power have been suggested; the following method of connection to an external source of current will in general be found the most convenient. It is practically the method proposed by Kapp. The machines are connected in parallel with each other to power mains giving voltage equal to that of the dynamos running at normal speed. (Fig. 6.)

The output of the dynamo is measured by an ammeter and voltmeter, and is supplied direct to the motor. The power supplied from the mains is similarly measured. The power given to the motor is thus the sum of the dynamo output and the power

supplied from the mains. The combined efficiency of the two machines is—

$$\frac{\text{output of dynamo}}{\text{input to motor}}.$$

The joint efficiency of the two machines is the product of the efficiency of each machine. Since the machines are of the same type and size, their efficiencies should be approximately equal.* Accordingly, it may be assumed that the efficiency of either is the square root of the combined efficiency determined by the experiment.

Thus, efficiency of each machine $= \sqrt{\frac{\text{output of dynamo}}{\text{input to motor}}}$.

It should be noted in connection with this method of testing that the loss of power is measured directly, and is a quantity of small dimensions compared with the output of the machines under test. Consequently, an error of small percentage made in this measurement will be exceedingly small compared with the output of the machines, and will only affect the value of the total efficiency to a correspondingly small extent. In carrying out the test, the machines are connected to mains giving approximately the normal voltage of the machines, and the power representing the losses is obtained by measuring the current taken from the mains.†

Two Coupled Dynamos Connected in Series.—Experiments in which machines are coupled together, so that one machine supplies part of the power required to drive the other, may be carried out in a considerable number of other ways. Another method may be mentioned, which, although not so easy to carry out as that just described, may be made to give more reliable results in the hands of a capable observer.

Fig. 9. In this case the two armatures are connected in series, and the extra power is supplied in the form of current equal in amount to the output of the generator, but at a lower voltage. In the previous experiment the machines were coupled in parallel instead of in series, and the extra power consisted of a supply of

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* This will not be exactly true even in the case of two machines which are absolutely identical, since the efficiency of a machine when operating as a motor will be less than when working as a generator; also the excitation of one of the machines is below the normal. The error introduced by this fact would make the efficiency of the machines appear slightly lower than its true value when working as dynamos; in most cases this error would be negligible.

† Full details of these and other methods of testing will be found in the Author's *Practical Testing of Dynamos and Motors*, published by the Scientific Publishing Co., Manchester.

current at practically the same voltage as that of the machines being tested, but small in amount.

The connections for the experiment are shown in fig. 9, the machine M acting as a motor to drive the machine G, which acts as a generator and contributes to the supply of power given to the armature of M. It will be seen that the two armatures are connected in opposition, brushes of the same polarity (marked + in the figure) being joined together.

In consequence of this method of connection the − brush of the generator G is shown to be connected to the + terminal of the source of supply. The generator is thus connected in series with the supply source in such a way as to add its voltage to that of the source. Consequently the voltage available at the terminals of the machine M is the sum of the voltages of G and of the source of supply.

Motor Testing.—It is most usual for motors to be loaded when under test by being coupled to a dynamo, the output of the dynamo being either absorbed in resistances, returned to the mains, or supplied to the motor in one of the methods detailed above.

The output of the motor in such cases is obtained by measuring the amperes and volts supplied by the generator, the efficiency of which must be known. In this way the output can be measured on delicate instruments with the same accuracy as the power supplied to the motor. This method is more convenient than the use of absorption brakes, which are generally considerably more trouble to apply to the motor and require a supply of water for cooling.

When brake tests have to be made on the customer's premises or elsewhere, the form which is generally the handiest for such high speeds as those of electrical machines is that of a flexible band of webbing or cotton rope from one end of which load weights may be conveniently hung, while the other end is attached to a spring balance secured to a fixed point of support. In order to damp small vibrations of the needle of balances of circular pattern the author has attached to the spindle of the needle a brass disc, the inertia of which has been effectual in securing steady readings. Where the adoption of a special pulley with internal rim for water cooling is not possible, as is frequently the case where tests are to be conducted on motors *in situ*, tests of power developed can only be taken for very short periods until the pulley becomes overheated, and time must then be allowed for the pulley to cool between successive readings. As a rough guide of the power which can be absorbed from a pulley of a given size without overheating, the following approximate rule may be used :

If b = breadth of pulley in inches,
d = diameter of pulley in inches,
H.P. = horse power to be absorbed,
then $b\,d$ = H.P. × 23·5 for air cooled pulleys,
or $b\,d$ = H.P. × 4·7 for water cooled pulleys.

With specially high speeds, and consequently light surface pressure, these values for $b\ d$ may be slightly exceeded.

Magnetic brakes have been introduced in certain cases with considerable success. In these brakes electro-magnets acting upon the rim of a pulley and flywheel induce eddy currents in the rim. In consequence of these eddy currents and the hysteresis of the material of the wheel a retarding pull is exerted, and the energy driving the wheel is converted into heat in the material of the rim.

There are two forms of such brakes. In the first the retarding pull is not directly measured, and the horse power absorbed can only be calculated from previous calibration of the apparatus. By means of this form of brake as much as 1,000 H.P. has been absorbed in a large flywheel.

In the second type of brake, fig. 10, the pull on the retarded wheel is balanced by a jockey weight sliding on a graduated lever. The power absorbed in this case is therefore calculated in exactly the same way as with an ordinary mechanical brake. The author has not actually employed a brake of this kind, but he has been informed that it is extremely easy and pleasant to work with.

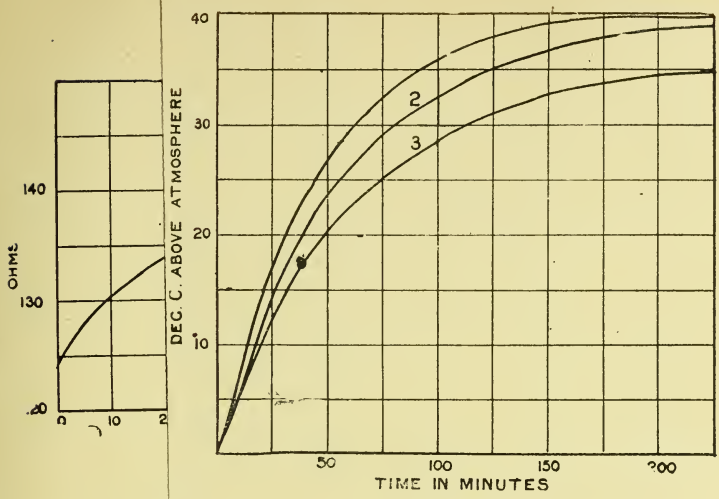

OHMS
140
130
120
10
2
DEG. C. ABOVE ATMOSPHERE
40
30
20
10
2
3
50
100
150
200
TIME IN MINUTES

FIG. 3.

VOLTS

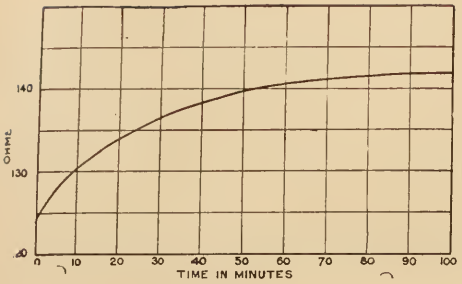


Fig. 1.

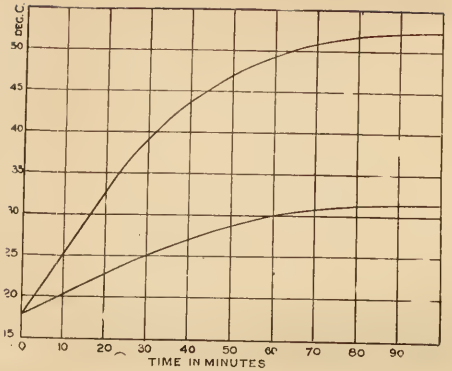


Fig. 2.

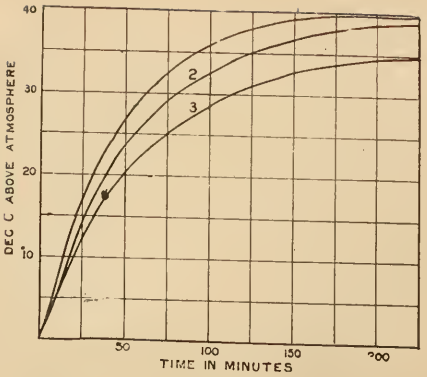


Fig. 3.

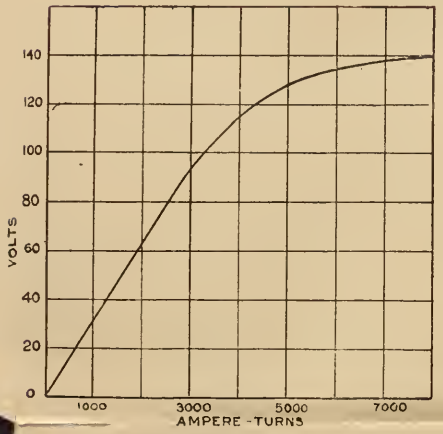


Fig. 4.

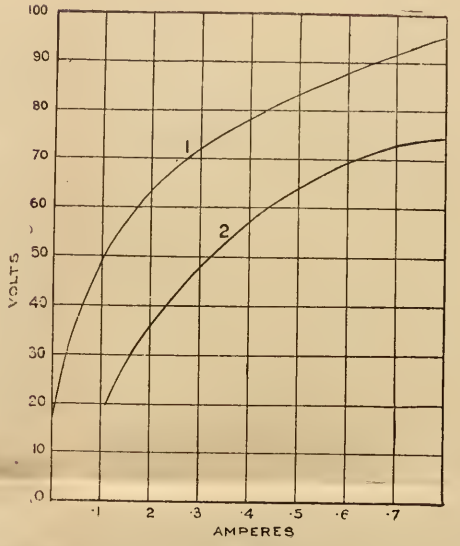


Fig. 5.

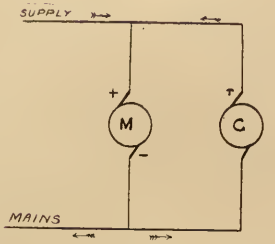


Fig. 6.

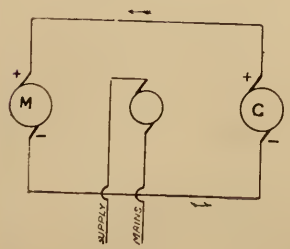


Fig. 7.

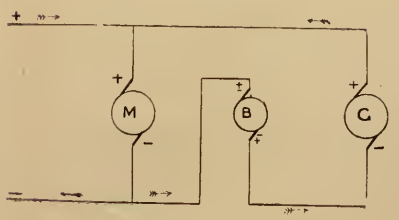


Fig. 8.

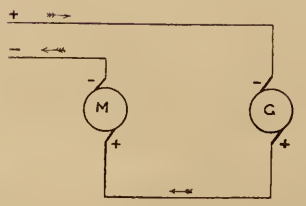


Fig. 9

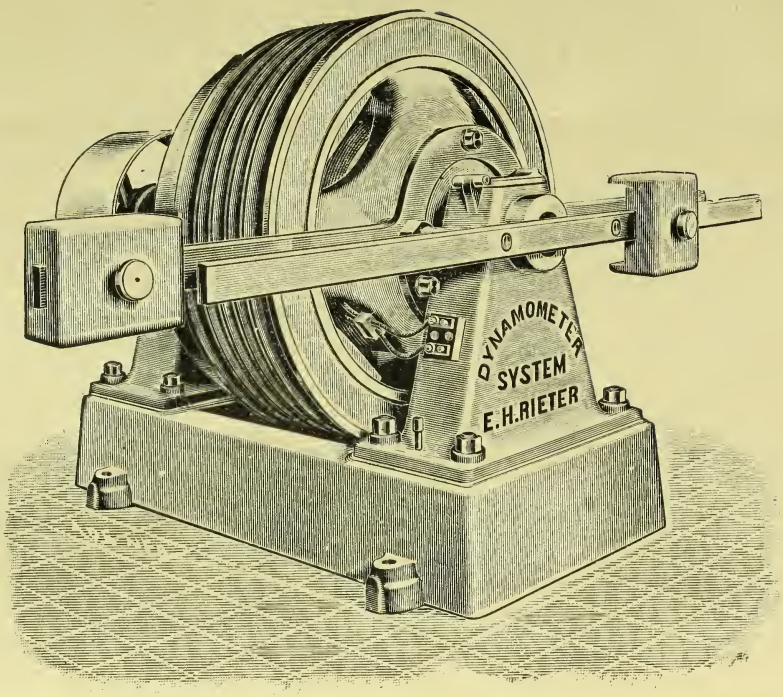


Fig. 10.

SUPERHEATING.

By C. L. Simpson, A.M.I.C.E.

[Read before the Society on Thursday, May 5th, 1904.]

To give you some idea of the progress that has been made in economy with the steam engine, I propose giving you some interesting examples, showing what the early pumping engine was and what it has been brought to at the present day.

We will commence with a "Newcomen" engine, which ran at York Water Works in 1785 and was put in by Smeaton. The photo is taken from an original drawing, which was found among my grandfather's papers, but which was presented to the York Water Works, as we considered that such a valuable drawing should go back to its original owners. This engine would do a duty of about 20,000,000 ft. lb. per 1 cwt. The next example is a Bolton & Watt Engine, which ran for more than a hundred years. It was erected in 1785, and was pulled out of Messrs. Whitbread's Brewery in 1887, and sent to the Museum in Sydney (N.S.W.).

On the 5th March, 1829, a four-wheel locomotive carriage, constructed by Sir James Anderson and Mr. W. H. James, in accordance with his patent of 1824-5, and weighing nearly 3 tons, was started in Epping Forest. It had two cylinders of only $3\frac{1}{2}$ in. in diameter, and was propelled by the hind wheels. With this apparatus the carriage, loaded with fifteen passengers, was propelled several miles on a rough gravelled road across Epping Forest, at a speed varying from twelve to fifteen miles per hour. The boilers were composed of common welded gas tubes, but the pressure of the steam, 300 lb. per sq. in., opened the seams of some of them, and by putting out the fire of one boiler, reduced the power of the engine, but still it returned home with twenty-four passengers, at the rate of about seven miles per hour.

By the end of the year, fresh boilers with better tubes were put in, and numerous experiments made with the engine. The greatest speed attained upon a level was three miles in twelve minutes, or at the rate of fifteen miles an hour.

The next example is a Cornish engine by Messrs. Harvey, of Hayle. It is one of the largest Beam Engines ever built; it was built in 1847 for draining the Haarlem Lake in Holland. Power 966 H.P. making 8 strokes per minute. It had an 84 in. high

pressure cylinder and a 144 in. low pressure cylinder, both having a stroke of 132 in. The cylinders were arranged annular, the H.P. being inside the L.P. There were eight pumps (see plan, fig. 1), each 84 in. in diameter by 132 in. stroke, the height to which the water was raised was about 12·5 ft., and the capacity of the plant about 253 million gallons per 24 hours. The "duty" of this engine would be about 60 million ft. lbs. per cwt. of best Welsh coal.

The next example we show you is one of the Compound Pumping Engines erected in 1851 at the Lambeth and Chelsea Water Works, Surbiton, Ditton, and built by Messrs. James Simpson & Co., Ltd. These engines did a duty of 111 million gallons per cwt. of best Welsh coal, with a boiler pressure of 40 lbs. They are fitted with piston steam valves and plunger pumps. They are known as the "Simpson" Engines.

Beam engines of various sizes and types have been built. The finest example that my firm have turned out is the pumping engine built about 1900 for the Chatham Water Works. The duty of this engine, with 80 lb. boiler pressure, was 120 millions (fig. 2). On a similar engine at the Colne Valley Water Works, using superheated steam, the duty was 137 millions, showing about 12 per cent. economy by adopting superheat.

I merely want to show that going over a period of more than a hundred years the progress in economical working has been very slow, but the interesting thing is that with 100° of superheat the economy is about 10 to 20 per cent. by using superheated steam.

As far back as 1853-4 the great "Brunel" thoroughly appreciated the paramount importance of economy in coal consumption on a voyage of great length. While building the Great Eastern Steam Ship he insisted on 25 lbs. per square inch of steam pressure, although the leading engineers of that time urged him not to go beyond 15 lbs. per square inch.

He proposed steam jacketing (with steam supplied from an auxiliary boiler of higher pressure than the main boilers), superheating, and improved jet-condensers, besides other devices for preventing waste of heat.

In 1859, in a paper read before the Institution of Mechanical Engineers, on Superheated Steam, by Mr. John Penn, several cases were referred to in which superheated steam was then being successfully used, and for some ten years afterwards superheaters were frequently applied, especially in Marine work.

In 1860 particulars were given of Parson & Pilgrim's method of superheating, as carried out on the boilers of passenger steamers then running on the Thames. This method consisted of cast-iron pipes placed in the fire grate, and showed that even in those days the importance was appreciated of placing the superheater near the furnace, and not merely in the uptake, to be

heated by waste gases, as was the case generally in the Marine practice of that time.

But in any early period of the history of superheating it was found generally that if superheating was carried beyond about from 400° F. to 500° F. trouble was liable to occur in the form of scored cylinders and valve faces, the cause of which was probably due to defective lubrication.

The tallow which was the lubricant of that time left a charred residue that was worse than useless for the purpose for which it was intended.

It was also found that the superheater tubes were sometimes burnt out, owing probably to a solid deposit on the inside of the superheater tubes through the use of salt feed-water. This was before the days of the surface condenser.

In 1857 Mr. Hirn issued a report of trials and experiments made by him on the value of superheating, which showed that a large gain might be expected from the use of superheated steam.

The boiler pressure used by him was 55 lbs., and with steam superheated from 410° F. to 490° F. he obtained economies of from 20 to 47 per cent.

Professor W. C. Unwin wrote a very interesting article on Superheating in November, 1894, which is very complete, and was published in *Cassier's Magazine:* this should be studied by all those who are interested in Superheated Steam. He there says: —

> "Between 1860 and 1870 Superheated Steam was very extensively adopted, especially for Marine engines. After 1870 its use was soon discontinued. The reasons for this were probably these:—(1) As the steam pressures used were increased the range of superheating possible within the limit of danger to the lubricant was decreased, and the advantages of superheating correspondingly diminished; (2) The large superheaters in the uptake proved, in some cases, to be dangerous and liable to become overheated; (3) As the designing of steam machinery became a matter of routine, and competition reduced the profits of engine building, the construction of engines fell into the hands of engineers who understood the action of the steam less well than the engineers who introduced superheating in 1859-60, and who regarded superheaters as unnecessary complications which it was convenient to abandon."

It was Professor Unwin who first called my firm's attention to what was being done in superheating, and in March of 1893 we fitted one of Schwoerer's Cast-Iron Superheaters to a Babcock and Wilcox's Boiler at the Grand Junction Waterworks, Hampton, which gave very interesting results, and quite justified its adoption. This was the first example of the re-introduction of

superheating to this country, and was carried out by Messrs. James Simpson & Co., Limited.

What you have to consider when you are considering the adoption of superheating to either an existing or a new plant is :—

(1) To what amount will you superheat ?
(2) How will this affect the high-pressure valves, piston rods, packings and working parts and joints ?
(3) What form of lubrication, and what lubricants are to be used ?
(4) What amount of non-conducting composition will be necessary to prevent radiation ?

My own experience shows that with from 100 to 150° F. you do not incur any difficulties with any steam plant, either old or new, providing you give all these above-mentioned points careful consideration. If it is an old plant it is well to see before adopting the superheat that the pistons, piston-rods, corliss or slide valves, slide valve rods, etc., are in good order, and it is best to have metallic packing made for superheated steam. It is well known that the superheat really only affects the high pressure cylinder, as after the point of cut-off the superheat disappears very rapidly.

Experience has shown that with the most refined type of engine under the above conditions an economy of 10 to 15 per cent. will be obtained. If the engine is of an uneconomical type the economy will be much greater.

On one experiment we carried out with a non-condensing engine we found that with 100° of superheat the economy was as much as 30 per cent. Taking another example of a similar boiler feed pump, we found under similar conditions the superheating practically halved the steam consumption of the donkey. On the first trials that were carried out on the Triple Expansion Worthington Pumping Engine at Kew Bridge, belonging to the Grand Junction Waterworks, we found that with 50° of superheat the economy was about 6 per cent., with 100° 10 per cent., with 120° as much as 15 per cent. In this case the coal economy followed in the same ratio.

The following table gives a rough idea of the economy resulting from superheated steam. If the saturated consumption be taken as 100 the consumption of superheated steam will be :—

Superheat at Engine.		Consumption. Turbine.		Reciprocating Engine.
0	...	100	...	100
50° F.	...	95	...	90
100° F.	...	90	...	81
150° F.	...	86	...	73
200° F.	...	81	...	66
300° F.	...	73	...	53
400° F.	...	66	...	44

The following are the figures for a trial at a Cotton Mill at Horbourg, of a compound Woolf Type Engine :—

	Superheated Steam.	Saturated Steam.
Duration of trial hours ...	11	11
Mean I.H P.	276	278
Steam per I.H.P. per hour	17·1	19·7
Coal, gross ,, ,,	2·4	3·2
Coal, nett. ,, ,,	2·0	2·7

The superheater which we have used in a great number of cases is composed of cast-iron tubes, having large corrugations both outside and inside ; the object of the former is to absorb the heat from the escaping gases, and that of the latter to give the steam circulating in the pipes the largest possible superheating surface.

Special attention has been given to the method of jointing the flanges of the pipes in this form of superheater, as the great difficulty which has always been found in making a thoroughly secure joint to withstand the high temperature, has never been thoroughly overcome. The joint is made by means of a ring of mild steel with cement of a special composition bolted in a soft state between the annular surfaces and squeezed together by the bolts. Before being placed in position the pipes are carefully tested to a pressure considerably over that at which they are designed to work. They are placed in the flue in a serpentine manner, and the steam taken from the stop valve on the boiler travels through them to the steam pipe to the engine room. In the case of the Babcock Boiler, the pipes were placed as shown in the highest part of the flue, where the temperature of the escaping gases is fairly constant, and the superheater requires no attention. Means are provided for blowing off any soot or dust that may collect or lie on the outside of the corrugations.

We have found that it is best to place the boiler stop valve on the engine side of the superheater, so that the superheater and boiler are one. This avoids any complication of steam stop valves, and gives no extra valves for the stoker to look after.

Where superheated steam is used the diameter of the steam pipe from boiler to engine should be as small as possible, a velocity through the pipes of 80 to 100 ft. per second or even more may be allowed. All steam pipes should be very carefully covered with a good non-conducting material.

We find that when the boiler is started to work, using due caution, vapor soon accumulates in the superheater, and we have not experienced any trouble by not flooding the superheater. We have come across cases where superheaters are flooded to commence with, then blown through before steam is turned on to the engine, and in some cases the steam pipe not being thoroughly drained of all water, the steam carries over water to

the engines, causing fracture of the cylinder covers and a breakdown.

In superheaters without flooding arrangements it is practically impossible for any water to reach the cylinders, even when the boiler is priming badly.

In adopting superheating to boilers, you want to very carefully consider all these points, and experience has shown that if everything is laid out in the first instance correctly, very great economy and good results would be obtained by adopting superheating.

The best place for a superheater in a Lancashire or Cornish boiler is at the end of the flue tubes. The temperature of the gases at that point is approximately 1,000° F., whereas in the uptake to the chimney they will only be about 400° F. to 500° F.

Hence if the superheater be placed in the hotter place it will receive $\frac{1000-350}{500-350}=\frac{650}{150}$ or, say, four times as much as if it were placed in the cooler place.

The following methods are in use for controlling the amount to which steam is superheated :—

(1) By the use of dampers regulating the flow of flue gases to the superheater.

(2) By mixing saturated and superheated steam in any desired proportions.

(3) By the use of an independently fired superheater. This arrangement lends itself very easily to the regulation of the superheat.

We have made a number of superheaters constructed with solid drawn tubes cast into cast iron ends, connected up with cast iron bends, and very similar to the Schwoerer Superheater. Here is an example.

I will give you an illustration of the latest form of superheater, which is made of solid drawn tubes, expanded into cast steel bends (fig. 3). This has been adopted, as many people do not like the idea of cast iron superheaters, although we have never had any trouble with them.

These superheaters are designed to have as much surface as the cast iron ones, and being constructed of solid drawn tubes, are preferred by some people.

Both on the Continent and in England superheaters have been adopted using a very high degree of superheat up to 700° F.

The steam consumption of these engines is very low indeed, and with compound engines some remarkable results have been attained. You, however, have the disadvantage with such an excessive amount of superheat, that you have to have specially constructed high-pressure cylinders, steam stop valves, steam piping, and auxiliary valves, and particular care has to be given

to the jointing. With such a high degree of superheat Corliss Valves are not used, and on the Continent they mostly use drop valves. Although with this system you get a very great economy in the steam consumption, yet the coal consumption does not follow quite in the same way. Supposing a boiler, before this high degree of superheat is adopted, evaporates 8 lbs. of steam per lb. of coal, you will find that with highly-superheated steam it will only evaporate, say $6\frac{1}{2}$, or when you come to balance up the "pros and cons" for highly-superheated steam against a moderate amount of superheat, you will find that the moderate amount of superheat on the yearly running will give the best results.

Objections are sometimes raised against superheaters being placed in the boiler flues on the score of reducing the draught. Such an objection is quite valueless, as with an ordinary water gauge it is impossible to detect any difference in the draught.

One occasionally hears of superheaters being scrapped as useless, but in the majority of cases this is through either ignorance or prejudice. Let me give you an instance.

"A" had five boilers. He was promised a saving of 15 per cent. if he adopted superheaters. He decided to give them a trial, and had them fitted to two of his boilers. After a year's running his total coal bill was found to be 9 per cent. less than formerly. He then complained that the saving was less than he had been promised, and either could not or would not understand that the saving was really $\frac{9 \times 5}{2} = 22\frac{1}{2}$ per cent. per boiler fitted with superheaters.

At St. Alban's Water Works, Godalming Water Works and Richmond Sewage Works, we carried out extensive trials on superheating, and found that using a moderate amount of superheat we got very good results indeed.

There have been some cases of application of superheating on board ship with good results, and you will find in Switzerland on some of the lake boats, built by Messrs. Suzler, that they have adopted superheating and are showing great economy.

Simpson & McPhail's Superheater.

The apparatus shewn in Fig. 4 consists of tubes connected by top and bottom boxes, which are divided into two compartments, connections to and from the superheater, and radiating pipes in the water space of the boiler and anti-priming pipe.

The steam passes from the anti-priming pipe to the connecting pipes, and then through the first compartment of the top box and through the first nest of superheater tubes to the first compartment of the bottom box and into the radiating pipes, which are placed in the water space of the boiler below the fire flues.

It then passes into the second compartment of the bottom box, and up through the second nest of superheater tubes to the second compartment of the top box, and by connections in the radiating pipes placed in the water space above the fire flues, and leaves the boiler at the stop valve.

Thus the steam is superheated twice, and then carried into the boiler twice, where it each time gives up a part of its superheat to the water in the boiler, and so practically increases the heating surface of the boiler.

By this arrangement the steam leaves the stop valve at a practically constant temperature.

By this arrangement also the amount of superheat for a given heating surface in the superheater is not so great as it would be otherwise, but we have the great advantage that the amount of superheat is practically constant, and so we avoid the risk of steam at unduly high temperatures reaching the engine and causing scoring of the cylinder walls, &c.

This superheater is constructed of steel throughout; the tubes are of cold solid drawn steel. The tube plate is of rolled mild steel $1\frac{3}{4}$ in. thick, and the boxes are of rolled mild steel plate, and are dished. Drain pipes are fitted to the bottom box to drain off any water that may collect there.

I propose finishing the paper with giving a few examples of the adaption of superheating to locomotives. There is a very interesting article on superheat, being comparative tests of locomotives using superheated and saturated steam, by Herr Strahl, in *Zeitschrift des Vereins Deutcher Ingenieure*, written this year. In this case the superheater consists of a cubical box placed in the centre of the boiler directly under the dome, and forming a watertight compartment about the flues. The front tube holes are larger than the rear, so that defective tubes can be withdrawn in the usual manner. The boiler steam is taken in at the top of the box, and after being led in a winding path about the boiler flues is delivered with the desired amount of superheat to the throttle valve in the dome. This forms a very compact superheater, but I have no particulars as to how the superheater stands after being at work for a lengthy period. The results given in this paper thoroughly justify going in for superheated steam.

Besides the Prussian Railways adopting superheated steam the Canadian Pacific Railway, the Alsace-Lorraine State Railway, the Belgian State Railways, the Moscow-Casan Railway, the Southern Railways of Italy, the Munich Suburban Railway, the Cape Government Railway Department, all are adopting superheat.

Taking a locomotive working with steam pressure of say 140 lbs. per square inch (the same pressure as that of the stationary engines tested at Manningtree, and previously referred

to), the normal temperature of saturated steam corresponding to this pressure is 361° F. Superheat this steam about 212° F. This superheat can be secured by an expenditure of about 10 per cent. of the heat produced on the grate, and the result is an increase in the volume of the steam of 25 per cent.; this means, in addition to a considerable economy, both in fuel and water, an increased efficiency of the boiler, inasmuch as the boiler supplies an increased amount of dry steam. The cylinder capacity then must be increased, and owing to the greater tenuity of superheated steam it can be worked economically at a very early cut-off. The efficiency of the engine is thereby increased, while its demands on the boiler are reduced; from this we see that given a limit of weight for any locomotive the use of superheated steam permits the reduction in the size of the boiler and in the steam pressure; an increase in the size of the cylinder and in the traction power. In England the road conditions impose a limit on locomotive boilers, and it has been a problem how to increase the power imposed by the road conditions. Superheated steam will no doubt play no mean part in solving this problem.

Superheated Steam Used on Locomotives.

In 1897 Mr. W. Schmidt, of Wilhelmhole, best known for his work in connection with superheated steam, proposed using superheaters on locomotives, and his plan met with favour by Mr. Garbe, one of the high officials of the Prussian State Railway.

Mr. Schmidt proposed to superheat the steam up to about 480° F. For this he conducted a portion of the flue gases through a wide flue at the bottom of the boiler to the smoke box, and there these gases entered the superheater at a very high temperature.

The superheater itself consisted of a collection of small tubes, through which the steam was made to pass on its way from the boiler to the cylinders, while the flue gases passed round the outside.

The superheating surface was about one quarter of the inside heating surface of the boiler.

The first superheated steam locomotive was built by the Vulcan Works at Stettin, and was delivered in 1898 to the Hanover division of the Prussian State Railway.

Several additional engines of the same type followed within the next two years, one of them having been built at the Borsig Works, and shown at the Paris Exhibition of 1900.

The weight of this engine was about 56 tons with a capacity of 300 tons of train load at a speed of 56 miles an hour on the level.

The high temperature of the furnace gases in the superheater,

and of the superheated steam itself led to a number of difficulties which, however, were gradually and successfully overcome by the painstaking efforts of Mr. Schmidt and Mr. Garbe, and a number of such engines, all of them non-compound and intended for passenger and goods traffic were built in 1901 and 1902.

Numerous trials were made of these locomotives, especially on the Hanover and the Saarbrucken division of the Prussian State Railway, and the results showed that the express engines were about equal in economy and capacity to the ordinary four-cylinder compounds, and that the goods engines yielded a small economy in coal for the same work, as compared with two-cylinder compounds of several tons less weight.

When in Berlin last October I was informed that Messrs. Borsig, Locomotive Builders, of Berlin, had built or were building 160 locomotives fitted with superheaters, showing the authorities must be satisfied with results of superheating.

Superheated Locomotive Steam Engines.

Turning to the Lancashire and Yorkshire Railway we find that one of the large express engines of the "1400" class, designed by Mr. J. F. A. Aspinall, in 1900, for the Lancashire and Yorkshire Railway, is fitted with a superheater. This is placed in the smoke box, which is of unusual length, in order to provide the necessary space required for the apparatus and its appurtenances.

The added length of the smoke box is not, however, noticeable from the outside, as the forward tube plate is recessed into the boiler for the necessary distance.

The superheater consists of a cylindrical shell having tube plates at either end.

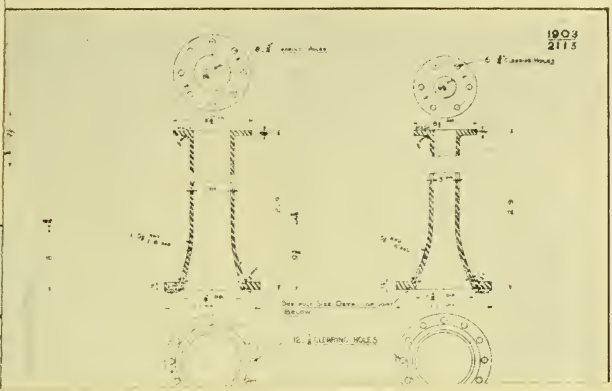
The tubes are slightly larger than those in the barrel of the boiler, so that when it is necessary to remove any of the latter groups they can be drawn through the superheater tubes and replaced in the same way.

The superheater can be bodily removed when it is necessary to have access to the boiler tubes for extensive repairs, sufficient space being allowed between the superheater shell and the inside of the smoke box to allow of the operation being carried out.

Diaphragms are placed in the superheater to make the steam pass through its entire volume on its way to the cylinders and the superheater tubes pass through these diaphragms.

The total area exposed to the steam in the superheater is 439·49 sq. ft., made up as follows :—

Inside of hand plate	40·63 sq. ft.
End plates...	29·48 sq. ft.
Tubes, outside diameter	360·26 sq. ft.
Jacket coil, outside diameter ...	9·12 sq. ft.
	439·49 sq. ft.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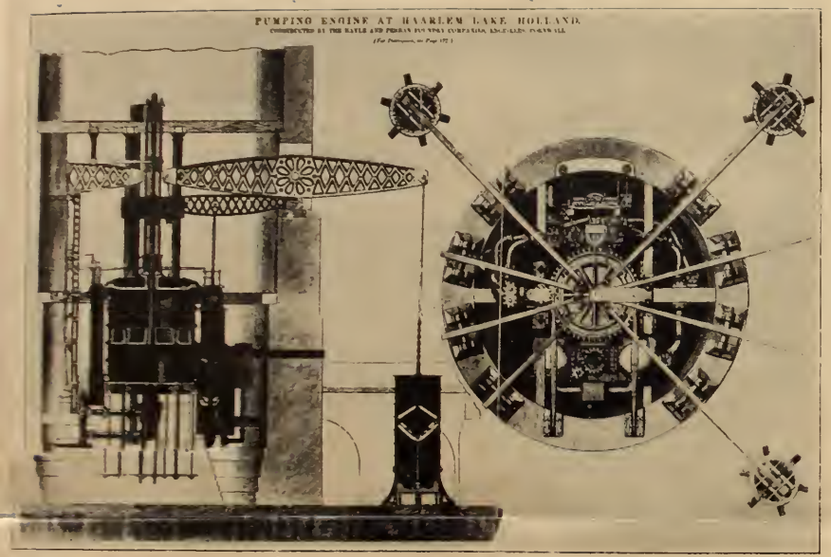

Fig. 1.

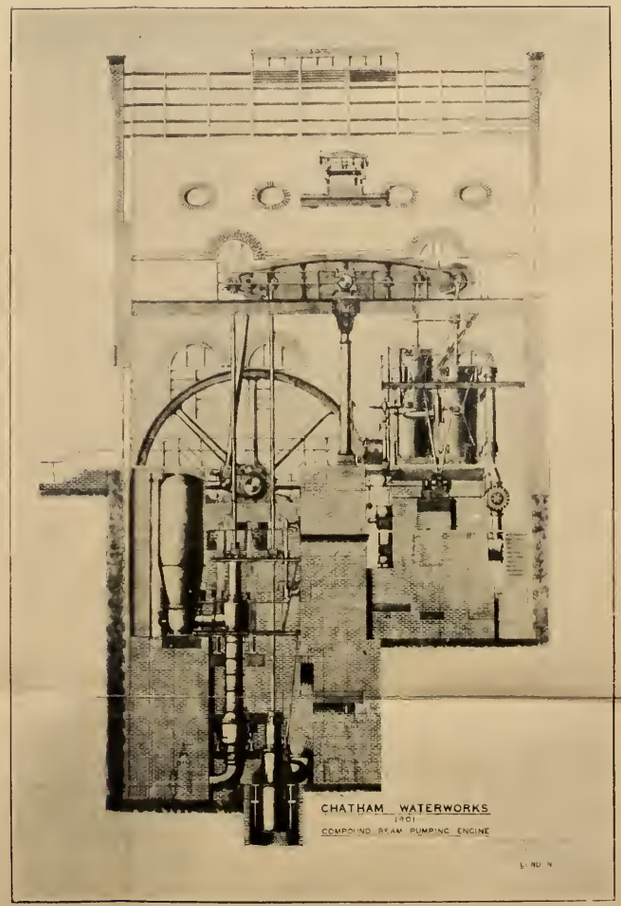

Fig 2

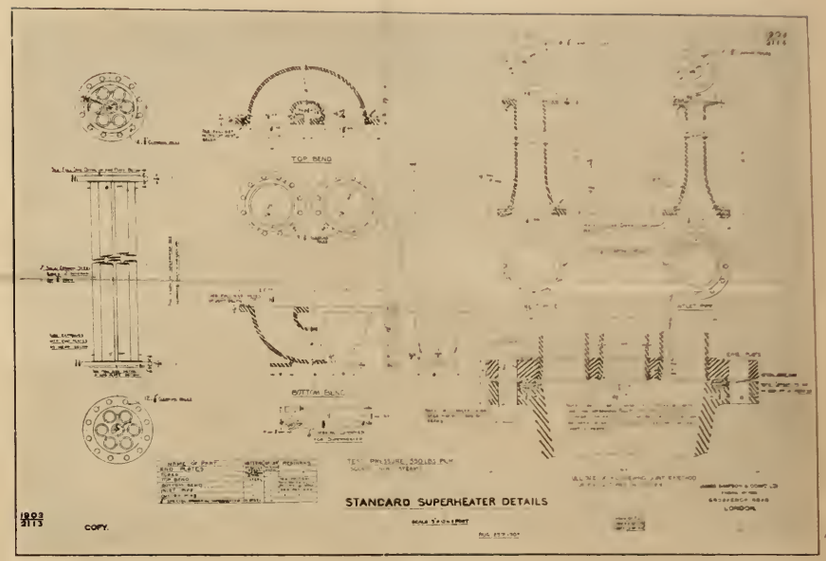

Fig. 3.

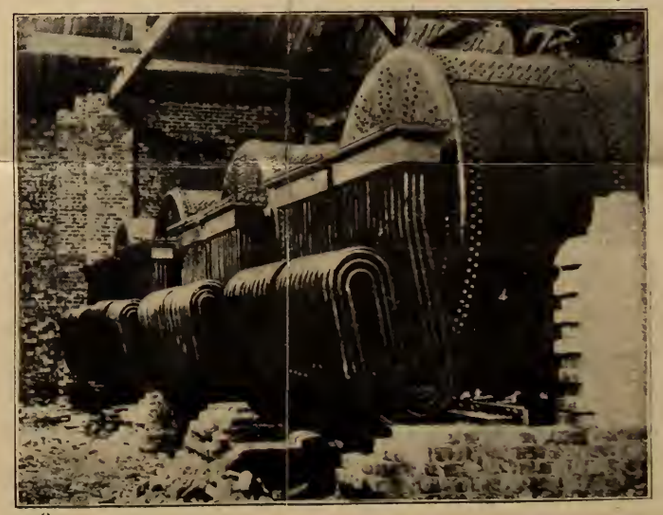

Fig. 4.

The value of superheated steam is clearly understood and appreciated by engineers, and now that the difficulties which formerly attended the lubrication of cylinders and the packing of the stuffing boxes have been almost if not entirely overcome, there would appear to be no adequate reason why it should not be more generally employed for locomotives.

Quite recently two more of these superheaters have been added.

MR. C. T. ALFRED HANSSEN, A.M.INST.C.E.

President of the Civil and Mechanical Engineers' Society, 1902-5.

TRANSACTIONS

OF THE

CIVIL AND MECHANICAL ENGINEERS' SOCIETY.

(Founded May 1859.)

46th SESSION 1904—1905.

EDITED BY

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A.C.G.I., A.M.I.C.E., M.R.S.I.,

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THE

Civil & Mechanical Engineers' Society.

(Founded May 1859.)

25, VICTORIA STREET, WESTMINSTER, LONDON, S.W.

(Telephone, 244, Victoria).

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The Society is not responsible for the statements made or the opinions expressed by the Authors of the papers in this volume.

The Society is indebted to the Editor of *Milling* for the loan of the blocks illustrating :—

"The Mechanics of Flour Milling," by A. R. Tattersall.

And to the Editor of the *St. Bride's Press, Limited*, for the loan of the blocks illustrating :—

"Thames Barrage," by James Casey, M.I.N.A.

Civil & Mechanical Engineers' Society.

TRANSACTIONS—SESSION 1904-5.

PRESIDENTIAL ADDRESS.

THE EFFECT OF PATENT LAW ON MODERN CIVILISATION.

By C. T. Alfred Hanssen, A.M.I.C.E.,
President of the Society.

[Read before the Society on November 3rd, 1904.]

The inadequacy of the reward accorded to inventors by Patent law has already been the subject of a presidential address this year by one of the leaders of our profession, the Hon. Charles A. Parsons, before the Engineering section of the British Association. I propose to devote my remarks to-night to the same subject, but before making any remarks with regard to what might be, I would first call attention to the vast benefits conferred upon this country by the present Patent law, inadequate though it undoubtedly is.

Looking back to the earliest dawn of history, we cannot but be struck by the absence of new inventions down to a very recent period. The tools and implements, the weapons of offence and defence, the domestic utensils, &c., which are represented on Egyptian and Assyrian monuments, were probably very similar to those which Noah brought out of the Ark, and they differed little from those used in Europe up to the time of the Reformation. Why should the human race, apparently so conservative, suddenly have commenced to invent new tools, new implements, new arms and new utensils, together with new methods of producing them in enormous quantities and of a quality and finish which surpasses the wildest dreams of antiquity ?

There was no lack of ingenuity among the ancient nations. Their buildings, their sculpture, their pottery, &c., still excite our admiration ; but there was no great departure from the beaten track—no startling innovations—to transform the world, before an Act of Parliament passed in this country A.D. 1624, for quite a different purpose, for the first time in the world's history gave to the Inventor of a new appliance a legal status and the power

to exercise his invention without fear of the cruel persecution which was formerly meted out to those who were given to making inventions.

The freedom and prosperity of the Hansiatic towns in Germany produced inventors of the very highest order, but as they had no legal protection for their inventions, their only remedy was to resort to secrecy. The invention of gunpowder, of printing, of drawing wire, of making china ware, and of many other useful arts were made in Germany during the Middle Ages up to the time of the Thirty Years' War, but owing to the secrecy wherewith their work was surrounded, it was, almost without exception, regarded as the result of witchcraft and direct co-operation with the Devil. The lot of the inventor was therefore far from being a happy one, and the stake or the rack seem to have claimed most of them as victims.

The powers of the Act known as James I. 21, chap. III., had probably no intention whatever of encouraging what they at that time would still have considered as witchcraft. They were suffering from a plague of monopolies. King Henry VIII. had been most liberal in rewarding his friends and companions with gifts of land, and had given away, or sold at nominal prices, so much of the Crown lands and confiscated Church property that there was very little left for his successors, Elizabeth and James, to bestow upon their faithful servants, and they therefore rewarded them by granting monopolies to manufacture or import some special commodity, until the whole of the manufactures and commerce of the country gradually got into the hands of monopolists.

The Act was therefore a compromise between the King and Parliament, which, while it still permitted the King to grant monopolies, restricted him to grant them for such industries and products which had not previously been known in Great Britain, and limited the duration of such monopolies to a term of 14 years. The intention was therefore that the hated monopolies, which formerly had hindered and retarded British trade, should now be used for furthering it, and as at that time the industry of France, Italy, Holland, and even Sweden, were more advanced than that of England, monopolies were granted to those who, becoming acquainted with manufacturing processes in use abroad, introduced them into England.

If King James had really foreseen the vast results which would flow from this Act he would amply have deserved the title of the Solomon of the North which he coveted so much, but it is quite certain that neither he himself, who strongly objected to the Act, nor his Parliament who induced him to sign it, had any real idea of what they were doing, for this Act may truly be called the commencement of a new era. Those inventions which had formerly been mere dreams of philosophers or toys for their

laboratories and museums, could now take bodily shape, as capitalists could engage in their manufacture with reasonable hope of legitimate gain, and it may be confidently asserted that the whole structure of modern civilisation is the direct outcome of the Patent laws. Without them Watt might certainly have speculated on the properties of steam, and made model steam engines for the Glasgow University, but he would never have induced a hard-headed business man like Boulton to spend the large sums of money necessary for carrying his ideas into practice if these ideas might have been copied by anybody as soon as their success was demonstrated.

The same thing holds good for every invention which has been made during the last two centuries, and the records of the British Patent Office contain descriptions of all these important inventions which have changed, first England, and afterwards the rest of Europe and its dependencies from the primitive state, which obtained during the reign of James I. to the present marvellous development of science of art. That this development was entirely due to the Patent laws is amply proved by the fact that it was exclusively in England that it took place until other countries introduced similar or even better Patent laws, and that the United States, which now offers the greatest inducement and best security for Patentees, is gradually taking the place which formerly belonged to England.

It cannot be too strongly maintained that the Patent laws and the material progress following from them are only responsible for the increased production of goods, that they have caused the things which mankind desires, such as food and clothing, houses and ships, weapons, ornaments and utensils, to be produced in far greater abundance than they ever were before, and that the drawbacks of civilisation, which consists of the excessively unequal distribution of these goods, depend upon altogether different laws into which we cannot at present inquire. It is however certain that with all the drawbacks of modern civilisation there are very few people willing to give it up and to return to the primitive conditions of life to be found in the rural districts of England and in the Colonies.

It appears to me as the very essence of fair play and common justice that those men who spend their genius and energy, their time and their money in producing the vast wealth we see around us would at least have an appreciable share of the wealth they produce. It was the wealth produced principally by Watts' steam engine, Hargreave's, Arkwright's and Crompton's spinning machinery which enabled England to emerge victorious from her long struggle with France in the beginning of last century, but if we inquire what share these inventors obtained of the vast wealth they produced we should certainly find it to be an almost ridiculous small fraction of a per cent. Watts would have got

nothing at all unless his patent had been extended over 31 years, and even then he does not appear to have obtained more than an ordinary commercial profit on the capital invested in the undertaking. The share obtained by George Stephenson and his heirs out of the £1,245,028,917 invested in railways in this country alone is equally infinitesimal. He actually lost money on building and selling locomotives, and only the more scientific and methodical management of his son Robert Stephenson saved the works from bankruptcy, and if we compare this meagre reward with that obtained by those fortunate individuals who owned land along the railway lines, it is thrown into still stronger relief. Not only were the values of their estates doubled or trebled, but they actually obtained compensation, which up to the present time amounts to about £200,000,000 or 20 per cent of the total capital expended on railways, merely for permitting the railway companies thus to increase the value of their estates. If the whole nation were equally benefited by the small reward given to the inventors, then the general happiness of such vast multitudes would afford the best possible reward that any public spirited man could wish for, but to see the greater part of these benefits absorbed by a single class of persons. numbering only about one per thousand of the nation, and to see them to a large extent squandered in useless and ostentatious display is surely most disheartening.

In order to illustrate the point it is instructive to consider a specific example. I have through the courtesy of the Estate Governors of the Dulwich College obtained a record, extending over 300 years, of the gradual increase on the rental value of this estate which may be considered an average sample of suburban property. In this case no objection can be made to the way the income is spent, as the whole of it is devoted to charity and education and Dulwich College is in every respect an ideal landlord, and the estate is characterised by an entire absence of slums and by large open spaces, making it like an oasis in the midst of the surrounding wilderness of bricks and mortar. The history of the estate is well-known, and it has been under the same management during the last 279 years. The name Dulwich was mentioned in a charter dated A.D. 967, by which it was granted by King Eadgar to one of his Thames. It is not mentioned in Domesday book but is referred to in a charter granted in 1127 by Henry I., by which it was given to the Priory of Bermondsey. It remained Church property until 1537-8, when all the land which included Bermondsey and Rotherhithe belonging to the Priory was confiscated by King Henry VIII. who, however, consented to pay the Prior a pension of 500 marks (£333 6s. 8d.) per annum. Dulwich Manor was in 1544 sold by the King to Mr. Thomas Calton, a London goldsmith, for the sum of £609 18s. 2d., and a yearly rent of

£1 13s. 9d., but it only remained in his family for 61 years, for his grandson, Sir Thomas Calton, who must have been an extravagant young man, seems to have got into debt and was obliged to sell the estate to Edward Alleyn, an actor and a friend of Shakespeare, who had lent him money. The estate at that time (A.D. 1605) appears to have comprised about 940 acres. The yearly rental was £320, and it is recorded in Young's History of Dulwich College that Sir Francis demanded 16 years purchase or £5120 for the estate, but that Mr. Alleyn objected to this as an excessive price and ultimately got it for £5000, or at the rate of £5 8s. per acre, including buildings. Alleyn bought a number of smaller plots of land and houses and increased the area of the estate to 1,100 acres, and succeeded in raising the income to £620 11s. 7d., but this included the rent from his theatre in Whitecross street, which he left in his will to the Dulwich College of God's Gift. The present area of the estate is given by the Estates Governors as 1200 acres, but I have not been able to ascertain when or at what price the additional 100 acres were acquired. The actual price paid by Alleyn for the whole estate,including buildings, seem to have been £7,504. Taking, however, the whole value of the 1,200 acres in 1626 to have been £8,200, and the rental £620 11s. 7d., we get the following astonishing returns on this wonderful investment :—

Anno Domini.	Annual Income of the Estate.	Per cent. on £8,200.	Total Increase per cent.	Interval of Years.	Increment of value per annm. per cent.
1	2	3	4	5	6
	£ s. d.	%			
1626	620 11 7	7·6	—	—	—
1728	1,368 13 3	16·7	9·1	102	0·089
1839	7,264 8 0	88·7	72·0	111	0·640
1843	7,333 17 11	89·5	0·8	4	0·200
1853	7,607 17 8	92·8	3·3	10	0·330
1858	9,760 13 8	119·0	26·2	5	5·240
1864	12,205 7 7	149·0	30·0	6	5·000
1874	15,984 0 3	195·0	46·0	10	4·600
1886	19,854 14 2	242·0	47·0	12	3·915
1892	20,826 1 0	254·0	12·0	6	2·000
1898	21,979 18 11	268·0	14·0	6	2·333
1903	22,002 3 3	268·5	0·5	5	0·100

The table shows that the interest on the original investment has increased gradually during 277 years at an average rate of 0·94 per cent. per annum, and that it has reached the enormous total of 268·5 per cent. per annum on the original investment.

Although the increment during the last five years shows a great decrease, this is more apparent than real, as the gradual falling in of the leases, together with all the improvements paid for by the tenants, constitute an additional income, which is only included in the amounts given in Column 2 to a very limited extent.

The importance of the above table is shown most distinctly in Column 6, which gives the annual increment in the interest on the first capital expenditure. Three periods may be clearly distinguished. The first from 1626 to 1728, where the increase in rent is very slow. It corresponds with the period where inventors still were groping in the dark, where means of communication were extremely defective, and each house was more or less a miniature factory, grinding its own corn, baking its own bread, brewing its own beer, spinning and weaving to produce the clothes needed by the household, and when labour therefore was very inefficient, so that no surplus was available for paying high rents.

The second period is from 1728 to 1853. The yearly increase in rent is nearly $4\frac{1}{2}$ times more than that of the previous period, and the increase in rent must certainly be attributed to the increased efficiency of labour due to the inventions of men like Hargreaves, Arkwright and Crompton, in spinning and weaving; Newcomen and Watt in producing power by the steam engine; Stephenson's locomotive and railways, the electric telegraph, and the numerous other inventions which enable large multitudes to live on a small area like London, and which thus provided a ready market for the Dulwich farmers, and also induced the more affluent classes to seek healthy homes in the distant village of Dulwich, instead of bringing up their families in the overcrowded area of London. But Dulwich was only indirectly affected by the great inventions during this period, as there was no regular water supply, no drainage, and no railway communication. The year 1853 may therefore be considered a turning-point in the history of the estate, as all these improvements were introduced about this time, and we consequently find the interest on the capital increasing as much as 5·24 per cent. per annum, or 59 times more than it did during the first period.

What I wish to emphasize is that this enormous increase in rent is entirely due to the advance in mechanical appliances which have so wonderfully increased the producing power of every worker, and have enabled them to pay such rents, and that therefore the short duration of patents for new inventions does not, by any means, abolish patent royalties, but only transfers them from the inventors to the landowners, so that the latter reap the magnificent harvest sown by the former. The plea therefore that a longer and more effective patent protection would injure British industries must be considered as altogether out of the question, for neither do the British industries, nor 99·9 per cent. of the British public at present derive any direct

monetary advantage from expired patents, as this monetary advantage is fully absorbed by the 0·1 per cent. of the nation who possess land, or to be more correct, by a small fraction of the 0·1 per cent. who possess land in or around large towns, and among whom many own estates where the increase in rent has been vastly greater and more rapid than in the case of Dulwich College Estate.

From a point of abstract justice there appears no reason why inventors should be treated differently from landowners; why the heirs of Arkwright, Watt, Stephenson, Bessemer and others should not go on century after century collecting their increasing royalties, unrestrained by any other law than that of supply and demand. If the patentee is a monopolist he monopolises only the creation of his own brain, and such articles which the human race can very well do without, for no one will deny that men lived fairly comfortably and probably more healthy lives before the introduction of spinning-jennies, steam engines, locomotives and steel rails. The landowners on the other hand monopolise one of the chief elements of human existence—the very source of all wealth—and without which the hnman race can no more exist than it could exist without air, water and sunlight, and they are therefore a greater menace to prosperity than patentees could possibly be, but I feel sure no responsible man would ever dream of claiming such extensive privileges for patentees. In further comparison of landowners with patentees, the difference between the two classes seems slight indeed. They both occasionally get their property very cheaply, and they often have to pay heavy prices for it, but while land is proverbially safe as an investment, the development of a patent is so risky that it is doubtful whether the would-be patentee might not have a better chance of increasing his capital by taking it to Epsom or Monte Carlo, or by investing it in any well-managed Continental lottery. This excessive risk is chiefly due to the many legal difficulties, disabilities, and pit-falls surrounding the path of an inventor, and as something like 20,000 patent specifications are published annually in this country alone, it becomes increasingly difficult to avoid anticipation which invalidates a patent, however successful it may be, and however impractical the anticipating patent may have been.

The whole tendency of the law seems to be to consider the patentee as an undesirable person who is plundering the community by means of his patent, and who therefore should be repressed as much as possible, and who is to be tolerated only as a necessary evil. I feel sure it would be to the advantage of all classes if such views could be changed, and the inventor were acknowledged as a pioneer of civilisation and the greatest wealth producer in the community, and if the laws were amended so as to encourage invention by making patents sufficiently safe as

investments, and of sufficiently long duration to repay the heavy expenditure generally incurred in developing a new invention, and in bringing it before the public.

When we see that even public houses, where the average profits are higher and the average risks much less than those developing new inventions, are to be compensated when their licenses are withdrawn, although they may have lasted many times 14 years, surely patentees may be encouraged to look for a somewhat more efficient protection for their property, as their present protection according to good legal advice is little more than "the right to go to law." Anyone who wishes to infringe a successful patent need only patent something which is not obviously a copy or a mechanical equivalent and the whole onus of prosecution and proof of validity lies with the original patentee, and it is quite certain that nothing is more difficult and costly to defend than a patent.

If once the importance of this matter is properly understood there cannot be any insurmountable difficulties in working out a plan whereby patents will obtain approximately the same validity as Acts of Parliament, but at a very much lower cost, and whereby the life of a patent can be suitably prolonged under proper conditions, and according to the capital spent in developing them. If patents, instead of being issued at a uniform rate of taxation were taxed according to the income derived from the monopoly, a very considerable revenue might be obtained from successful patents, while the charges for undeveloped inventions might be correspondingly lowered.

The effects of the scanty measure of justice hitherto meted out to inventors has been truly wonderful, and it has, as already stated, initiated a new era. Is it not reasonable to suppose that a fuller measure of justice and security would give far more brilliant results than have hitherto been obtained? and that the country which adopts such a policy will also obtain the industrial and commercial lead which England enjoyed throughout nearly the whole of last century but which she now appears to be losing? Germans who possessed inventive genius formerly emigrated to England or America in order to find suitable protection for their inventions, which was denied them at home, and German industries suffered in consequence, and they were far behind those of England. The present great development of the German industries dates distinctly from the present German Patent laws, which in many respects are better than those of England, and induce inventors to stay at home and to develop their own industries instead of those of other countries. The German Government was formerly of the opinion that it was more profitable for their manufacturers to obtain new inventions without paying for them, but they have found out their mistake and thus verified the true proverb that "Righteousness exalteth a nation, but sin is a reproach to any people."

NOTES ON PORTLAND CEMENT.

By Herbert E. Bellamy

(City Engineer, Rockhampton, Queensland).

[Read before the Society on Thursday, 8th December, 1904.]

Introductory Observations.

There is hardly any material used by the Engineer, Architect, or Builder which is of so much importance and interest as Portland Cement.

During the past few years the author has carried out several works which have necessitated the use of some thousands of casks of cement. He has studied the question carefully, and carried out many experiments with English, Foreign and Colonial cements. He is also surprised at the large quantities of foreign cements which find their way into the Colonial market. One of the chief reasons for this is the recognised fact that some foreign cements will stand as much as 600 lbs. on the sectional area of one square inch, after seven days mixing, without breaking. The author has recently tested two brands of Alsen's and White Horse cements after they had been mixed only 48 hours, and they gave a result of 410 and 390 lbs. on the square inch respectively. With English cements he has never as yet obtained such results. The danger of these high tests will be pointed out below. He has, on the other hand, found that the English cements are much more congruous and constant in the results of testing than the above mentioned. Another reason for the large demand for foreign cement is its quick setting properties. The usefulness of this latter property manifested itself to the author in carrying out several miles of concrete curbing and channelling in streets during the past few months.

Portland cement differs very considerably in its characteristics and action according to its quality. It can be manufactured more cheaply when underburnt, because then a greater bulk of cement is produced with a given quantity of material, and it requires less fuel and less grinding; it also sets more quickly, but never arrives at the same ultimate strength as a properly burnt cement. Under-burnt cement contains, moreover, an excess of free quicklime, which is apt to slake in the work and cause great mischief. This may be remedied by exposing the

cement, and allowing these particles to become air-slaked. It might be interesting to mention that in the construction of the Lake Vyrnwy dam the cement was exposed before use to the humid atmosphere of a room for 10 to 14 days in thin layers.

In specifications one often finds the following clause :—

> "The cement shall for a period of 14 days before being used be spread in a layer of about 6 in. in thickness on a dry-boarded floor under cover, and be there turned over every second day at least to cool."

The Cement Trade section of the London Chamber of Commerce adopted the following resolution in 1898, after much valuable evidence had been obtained from various experts, and including, among others, Mr. D. B. Butler :—

> "That Portland Cement be defined as a mixture of two or more suitable materials, intimately and artifically mixed in the requisite proportions, and afterwards properly calcined and ground, to which nothing has been added during or after calcination, excepting that an addition not exceeding 2 per cent. of gypsum is permissible for the purpose of regulating the setting.'

That the following rule be adopted :—

> "That if any material whatever, excepting 2 per cent. of gypsum, for the purpose of regulating the setting, be added to the Portland cement clinker during or after calcination, the article so produced shall not be sold as Portland cement, but under some other distinctive name."

The above resolution was based on the evidence of various experts.

Further, they reported that gypsum added to the cement for the purpose of regulating the setting time, in quantities not exceeding 2 per cent. of the weight of the cement, has no deleterious influence on the quality of the cement.

In the year 1877 the German manufacturers of Portland Cement formed a Union, and in the following year this Union published certain "Standards for the uniform supply and testing of Portland Cement," which had been approved by the Chief Officials in the Prussian Department of Public Works. These were published with a view to excluding rival products of inferior quality from the German market.

In 1887 the Prussian Ministers for Commerce and Industry and for Public Works issued an ordinance to the officials in their departments enjoining the observance of the "Revised Testing Standards," and in the course of the same year these received recognition in the other States of the German Confederation. In reality, the "Standards for the uniform supplying and testing of Portland Cement," of the year 1887, form still the basis for testing Portland Cement in the German Empire.

The standards are prefaced by the following definition of Portland Cement :—

> "Portland Cement is a product obtained by first burning an intimate mixture of substances containing lime and clay as essential ingredients, until a shrunken mass is formed, and then finely pulverising the resulting mass."

This definition was made in consequence of the practice, begun in the year 1882, of mixing slag from smelting furnaces, in a finely ground condition with Portland cement, a practice which the Association of German cement manufacturers feared would lead to the decline of the German cement industry. The Association opposed the practice of mixing from the outset by means of the following resolution passed in July, 1882 :—

> "The General Assembly of the Association of German Cement Manufacturers declares that the sale of cemen tto which foreign bodies of inferior value have been added after the burning as Portland cement is to be considered a deceiving of the purchaser, unless at the sale and on delivery of such mixed goods, plain notice is given to the purchaser that such additions are in the cement. Additions to the extent of 2 per cent. of the weight made only for the purpose of imparting particular qualities to the cement are, however, not to be regarded as adulterations."

After the issuing of the Revised Standard the Association imposed upon the members the following regulations :—

> "Members of the Association are allowed to bring into commerce under the denomination of 'Portland Cement' only such a product as is obtained by burning an intimate mixture of substances containing lime and clay as essential ingredients until a shrunken mass is formed and then finely pulverising the resultant mass. They are under the obligation not to recognise as Portland cement products formed in any other way than the above, or products to which foreign bodies have been added, either during or after the process of burning, and they bind themselves to regard the sale of such products under the denomination of Portland cement as a deceiving of the purchaser. Small additions to the extent of 2 per cent required for regulating the time of setting of the Portland cement, are, however, not included in this obligation. If a member of the Association infringes the above obligations, he shall be excluded from the Association, and the fact of his exclusion made known publicly."

In Germany, cements which contain more than 2 per cent. of gypsum are inadmissible, because they are not stable in volume. Also cements burnt to a shrunken mass which contains more than 3 per cent. of magnesia are to be regarded as dangerous,

because they are liable, after a considerable time, to begin to expand.

Historical References.

Portland cement is so called from a fancied resemblance in its colour and strength to Portland stone

It was first made from a mixture of lime and clay which was reduced to powder at a high temperature in a kiln.

In the year 1824, one Joseph Aspdin, a bricklayer, resident in Leeds, Yorkshire, applied for the first patent in connection with it, and established a factory in Wakefield in the following year.

In the year 1828, this cement was used by Sir Mark Isambard Brunel, a native of France, in the construction of the celebrated tunnel under the River Thames.

In 1826, Major Sir J. W. Pasley conducted some experiments, and produced a good hydraulic cement made from Thames clay and chalk. These latter materials, however, were not always to be obtained in the vicinity where the cement was manufactured, and, owing to this fact, blue clay was used in some places in the stead of Thames clay, the results being highly satisfactory.

The crushing machinery made about this time for the manufacture of cement was of a very primitive form. Indeed, the cement was sometimes broken into small pieces with the aid of hammers, and then rudely ground between stones. More thought was at that time bestowed upon the mechanical mixture of the clay and chalk than upon their chemical composition.

In 1859, Mr. Grant, the then Engineer of the Metropolitan Board of Works, London, commenced some exceedingly valuable experiments in connection with its use on the London Main Drainage Works, when, with more knowledge of its important qualities, its employment became general by Engineers, Architects, Builders and others.

Mr. Goreham was the first to point out the advantage of limiting the quantity of water used in the manufacturing process.

Previous to about the year 1850, the manufacture of cement had been confined almost exclusively to England, but it was quickly taken up on the Continent and it is now made in America and in nearly all the Colonies.

In 1877, Thomas Russell Crampton, M.I.C.E., patented a process for burning cement in rotary kilns.

In 1885, a patent was taken out by Frederick Ransome, Assoc.M.Inst.C.E., for a rotary kiln, and this kiln may be regarded as the foundation of modern rotary kilns.

Since 1885, many improvements have taken place in the construction of rotary kilns, and it appears from all reports that the method must supersede all the older processes carried on in Europe.

Manufacture of Cement.

The author would refer to the paper on this subject, by Messrs. Stanger & Blount, presented to the Institution of Civil Engineers, in February, 1901, entitled "The Rotary Kiln Process of Cement Manufacture."

The following figures, taken from the reports of the United States Geological Survey, show the growing popularity of the rotary kiln in the United States :—

Number of Barrels Produced.

Year.	Rotary Kilns.	Fixed Kilns.
1893 ...	149,000 ...	441,000
1894 ...	242,000 ...	556,000
1895 ...	400,000 ...	589,000
1896 ..	632,000 ...	910,000
1897 ...	1,311,000 ...	1,366,000
1898 ...	2,170,000 ...	1,521,000

In cement making, as in all other great manufacturing processes, fuel and power have been substituted for labour, with a substantial decrease in the cost of production, and gain in the quality of the product.

Portland Cement may be said to be of the following composition :—Lime, 60 to 64 per cent. ; silica, 20 to 24 per cent, (silica is an acid formed by the union of oxygen with the element silicon. It is the principal ingredient in sand); alumina, 6 to 10 per cent. (alumina is a metallic oxide, composed of oxygen and the metal aluminium, and is the base of clays) ; and oxide of iron, magnesia, &c., 3 to 5 per cent.

The converting of these raw materials into the finished product consists essentially of three distinct stages. The first is the mechanical mixing of the necessary ingredients, the second is the change caused by calcining these materials, and the third is the grinding of this calcined product.

There are three general ways of manufacturing cement. The first is described as the "wet process," the second as the "semi-wet," and the third as the "dry" process.

In the first or "wet" process certain proportions of chalk and clay are mixed in water to the condition of a creamy liquid, which is known as "slurry" or "slip," the fine particles in suspension are allowed to settle in large tanks for several weeks, and when the deposit becomes nearly solid the water is run off, the residue is dug out, sometimes pugged, dried on iron plates over coking ovens or over the flues from the kiln, burnt in intermittent kilns at a very high temperature, and then ground to a fine powder.

In the "semi-wet" process the materials have first to be ground in machines before the final mixing. The analysis of the "slurry" should be carried out daily by the manufacturer. This

will enable him to know whether the correct proportions of clay and chalk are put into the mixing mill.

In the third, or "dry" process, the clay is dried, then mixed with the limestone, crushed and ground into a fine powder. This powder is passed into a pug mill, where it is thoroughly mixed and sufficient water is added to enable it to be pressed into forms like bricks. These bricks are dried, and afterwards calcined. Dry slurry contains about 77 per cent. of calcium carbonate.

Calcining.—Several methods have been introduced and adopted for calcining. After the mechanical mixing, the slurry is burnt into a state of semi-fusion, forming into clinkers, when the chief chemical action occurs, for the water and the carbon dioxide being driven off, calcium silicate and calcium aluminate are formed. The clinkers are removed from the kilns, and carefully examined. All the lustrous slag or powdered ash due to overburning is rejected, as also is insufficiently calcined slurry. A well-burnt clinker has a dark appearance. The selected materials are then subjected to a treatment which reduces the sizes of the clinkers previous to grinding.

Grinding.—The common process of grinding cement is by feeding it between horizontal mill stones of the bed stone and runner type.

After the process of grinding, the cement is stored in damp proof sheds for air slacking, so as to get rid of any excess of lime which may be present. If there should be any doubt that this process has been neglected, it would be well to have the cement, when delivered on to works, emptied on to a perfectly dry platform in a layer not exceeding 3 ft. in thickness.

The fineness to which a cement is ground determines its usefulness, because when a finely-ground cement is mixed with sand it gives a much higher average strength than that mixed with a coarse ground cement. The finer a cement is ground, however, the more costly it becomes.

Testing Cement.

The Engineer, Architect, or Builder is confronted by no problem more difficult than to say whether a particular kind of cement, when placed in any work, will behave in a predetermined way. Especially is this true with an artificial cement. Other cements are more reliable under conditions of exposure, for which they are suited. The difficulties arise from the fact that tests must be made on a product not in its final stage. A cement, when mixed with concrete, undergoes chemical and other changes in the process of final setting, so that the material subjected to stresses in the work is not the material tested, but a derivative of it.

The object of testing cement is to determine two factors. First, whether the product of a cement will attain the desired

strength quickly enough to enable it to bear safely all stresses designed for it; second, whether it will afterwards fall below that desired strength.

The most useful tests of cement are those which connect themselves with the defects to which cements are subject, or with some merit which they should possess; and, again, which can be made in the minimum of time with the least apparatus and trouble, and are entirely free from that personal equation which enters into the whole question.

It is necessary to state that all the testing appliances should be of good design and of modern manufacture. The tester should not neglect to observe the least of the many points necessary for a true test.

Preference should be given to a testing machine which applies the load at the rate of 400 lbs. in one minute.

Difficulties are experienced in working the machine at so slow a speed, the impulse being jerky when applied slowly by the hand. The author has obtained a difference of 40 per cent. between two briquettes mixed both from the same cask of cement when the times were 36 and 60 seconds for the tests respectively. The tests which will be described are as follows:—

(1) Colour.
(2) Specific Gravity.
(3) Grinding.
(4) Setting properties.
(5) Strength.
(6) Soundness.
(7) Coolness.
(8) Miscellaneous Tests.

The Engineer selects samples from every tenth barrel, or from the equivalent of the tenth barrel when packed in sacks, taking care to properly mark all the casks in the batch. Each sample should fill a 4 in. air tight cubical box, and should be sent for testing immediately.

No averaging should on any account be allowed in testing.

The author has drawn up four diagrams illustrating how a complete record of tests can be kept for official reference for any period. As they explain themselves there is no necessity to enter into an elaborate description of them.

Tests.

(1) *Colour.*—Good Portland cement should be of a grey or greenish grey colour. A browny colour indicates an excess of clay and shows the cement is inferior. A coarse bluish grey cement shows that it is probably over limed. The colour may best be observed by rubbing the cement on a piece of white paper.

(2) *Test for Specific Gravity.*—This test should always be carried out. Experiments which the author has made shows that the specific gravity of good K. B. & S. English cement slightly exceeded 3·0, while an inferior cement was only 2·8.

Adulterations of Portland cement most likely to be practised are made with materials which reduce the specific gravity. The test is therefore exceedingly valuable in determining a properly burned, non-adulterated Portland. No other hydraulic cement is so dense. The weight of Portland cement varies from 95 lbs. to 120 lbs. per striked bushel (21 bushels are equal to one cubic yard).

The specific gravity of cements can be ascertained by Keate's specific gravity bottle, as described by Mr. Grant.

The bottle consists of two bulbs, the lower somewhat exceeding the upper in capacity. The exact capacity of the lower bulb is of no importance. On the neck between the bulbs is a file mark *b;* on the neck of the upper bulb is a similar mark *a.*

The capacity of the upper bulb between the marks *a* and *b* must be determined, and may conveniently be 500 or 1,000 grains in water measure at 60° F.

In ascertaining the specific gravity of a solid in small fragments—small shot, for example—the following is the mode of procedure :—Fill the bottle with distilled water up to the mark *b ;* counterpoise the bottle so filled in a balance ; drop the substance of which the specific gravity is to be taken gradually into the bottle until the water rises from *b* to *a.* Ascertain the weight of the material so added. If the capacity of the upper bulb be 1,000 grains of water the weight of the material required to raise the water from *b* to *a* is its specific gravity. If the capacity of the upper bulb be 500 grains of water the weight of the substance added must be multiplied by two. The result will be the specific gravity.

The principle of the apparatus is very simple. The capacity of the upper bulb is an exact measure of distilled water, and when the water is raised from *b* to *a* by dropping a solid into the bottle, the bulk of that solid, equivalent to the given volume of the distilled water, is ascertained, and the relation between the weights of the two is given by the weights of the substances added.

The only precautions are that the air, which is apt to cling somewhat to the solid matter when dropped into the liquid, is carefully removed, and that if a very volatile liquid be used in the place of water the bottle should be corked to prevent evaporation.

With natural cements this test may be dispensed with.

(3) *Test of Grinding.*—It is a well established fact that other things being equal, the finer the cement, the greater will its sand carrying capacity be—that is, it will show much greater

strength with the same charge of sand, or equal strength with a greater charge. There is no doubt but that the cementitious value of the material resides in the very fine part. Very few specifications state how much cement is to be operated on for this test, or how long the sieving process is to continue. Considerable difficulty is usually experienced in preventing the meshes of the sieve from clogging up. The author insists on the screens of all sieves being examined with a magnifying glass once a week to see that there are no apertures larger than the normal ones. The specification for the works of the Forth Bridge required that the cement should pass a sieve containing 2,500 meshes to the square inch, leaving a residue of not more than 5 per cent. by weight. The test of rubbing cement between the fingers is a practice to be condemned. The gauge of the wire of the sieves should be clearly stated in ordering.—For a sieve of 2,500 meshes the gauge should be No. 37 S. W. G.

New Tests for Fineness.

To ascertain the cementitious value of the material, a new form of testing apparatus—known as the Goreham Flourometer—has lately been devised. It is of very simple construction:—(1) A conical glass into which the sample of cement is placed; (2) a brass tube having a serrated end passing through the cement, and resting on the bottom of the glass; (3) a sheet metal tube to the lower end of which the test glass is secured by suitable clamps (the upper end has an air-tight cap, through which passes the top of the brass tube, whilst from the upper portion of the tube a branch pipe of equal diameter projects downwards at an acute angle); and (4) a cylindrical settling chamber, receiving the branch pipe through its side. The settling chamber is covered by a closely fitting lid, and all the joints of the apparatus are made air-tight. An aerometer is generally employed for the provision of air at a definite pressure, the air being conveyed from the aerometer to the brass tube by an indiarubber pipe. The method followed in the course of a test is also very simple. A weighed sample of the material is placed in the glass vessel, which is then clamped to the end of the metal tube; a stopcock on the air tube is opened, and as air issues from the serrations of the brass tubes it carries away the impalpable portion of the cement, which passes up the sheet metal tube, and through the branch pipe into the settling cylinder. When no more cement flour is given off, or after the lapse of a specified time, the glass is removed and the residue is weighed. It is then easy to determine the proportion of active material taken over by the air. Mr. Goreham, the inventor, states that he has made a number of tests with different samples of commercial cement, and in these the proportion of flour was found to vary from 20 to 50 per cent., the residuum being therefore from 80 to 50 per cent. In a sieve

test the proportion of fine material passing the meshes would be much greater, but when samples of the same cements were thus tested for comparison, the variation was not more than 1 per cent. The flourometer tests for fineness is not intended to supersede recognised tests for other properties of cement, but there is no doubt that it will be found in every way reliable.

The effect of fine grinding upon weight is shown in the following results obtained by Messrs. Currie & Co., of Leith :—

Meshes per sq. inch of sieve.	Percentage retained by sieve.	Weight in lb. of cement per bushel.	Weight in lb. of cement per cubic foot.
2,500	10	115	90
3,600	10	112	87
5,500	10	109	85
14,400	10	104	81
32,000	10	98	76

(4) *Test of Setting Properties.*—This test is made by gauging the cement with water and observing the times of initial and permanent set. The Vicat and Gilmore needles are generally used for ascertaining the rate of setting of cements.

Some engineers are against this test, but the author considers the following might be included in a specification :—"Initial setting as ascertained by the Vicat needle must not take place in less than 25 minutes, nor final setting under two hours." As the Vicat needle is well known there is no necessity to describe it. The Gilmore needles consist of (1) a steel needle one twelfth of an inch in diameter loaded with a weight of $\frac{1}{4}$ lb and (2) of a steel needle one twenty-fourth of an inch in diameter and a weight of 1 lb. In use, the points of the needles rests upon the specimens, and are held between the fingers in a vertical position. The moment when the coarse needle fails to sink into the cement is called the time of initial setting, when the fine needle no longer penetrates, the moment of final setting. Generally speaking, both periods of setting are prolonged by increase of moisture, and shortened by increase of temperature. In damp weather, care should be taken to see that the samples are thoroughly dried before water is added.

(5) *Tests of Strength.*—These may be divided into compressive and tensile tests, the latter including the transverse test made by breaking a beam of the cement. Tests of compression are certainly of some importance, but the apparatus required is rather cumbersome, and these tests are very rarely carried out. The ratio of compressive to tensile strength of the same class of cement is perfectly uniform. It may be assumed that resistance to compression is about 20 times that of the tensile strength.

This test need not be further considered, as it gives no surer indications than the tensile test. The tensile test is theoretically a perfect index of the cement at the time of test, but a comparison at different periods gives the best obtainable indication of what its subsequent conduct will be. The two periods usually adopted are 7 and 28 days respectively after mixing. The one day test should not be placed in the same category as the other tests named. The object of tensile tests is to ascertain the greatest stress per square inch which the cement can be made to stand under given conditions without rupture.

Neat Test.—" Place the amount to be mixed on a smooth non-absorbent slab (a ground glass plate 24 in. by 24 in. is suitable); make a crater in the middle sufficient to hold all the water, add all the water required at once; mix thoroughly by turning with the trowel for five minutes. Place a brass mould on a slab. Fill the mould with consecutive layers of cement, each when rammed to be a $\frac{1}{4}$ in. thick. After filling the mould and ramming the last layer strike smooth with the trowel, and cover the same with a moist cloth for 24 hours. The mould should be tapped gently to prevent it adhering to the slab. After the 24 hours, remove the briquette from the mould and immerse it into fresh water for six days. The briquettes should be placed face down in the water. For this test 20 per cent. of water by weight should be used." The briquettes should all be numbered.

To measure tensile strength a machine which applies the stress automatically at a uniform rate is preferable to one controlled entirely by hand. The test must be made immediately after taking the briquettes out of the water, and while they are still wet. The standard breaking weight usually specified is 400 lb. on the sectional area of one square inch. The tensile strength of Portland cement has been increased during the past decade. There are some cements which will stand a tensile stress of 600 lb. per square inch. Now, there is great danger in raising this test too high. A cement having great tensile strength after a short interval of setting can be obtained only by using a maximum amount of lime in the manufacture, and an excess of lime in the cement may cause it to expand in the work months after it is used. Over-limed cements are totally unfit for use in sea water.

The test above mentioned applies to the seven days test. It has been suggested that seven days is too short a period for its properties fully to develop, and a period of 28 days has been recommended in order to give it a fair and reasonable trial. There is a great practical disadvantage in having to keep a consignment of cement 28 days before it is accepted or rejected, otherwise the longer period is preferable. When this latter test is compulsory, it is usual to specify that the breaking weight shall not be less than 500 lb. per square inch.

Testing with Sand.—For many years Portland cement was always tested neat. The concensus of opinion, however, is that the test with sand, prescribed by the German Government, viz :— Three parts of sand to one of cement is preferable, as it more nearly approaches the condition under which cement is used. Especially is this test essential if the mortar is to be used in work on the " Monier " system.

The test is made on briquettes after 28 days setting. The length of time required for this test with sand renders it difficult to carry out on ordinary works for want of storage room, and it has other disadvantages. It is impossible to compare tests made with mixtures of cement and sand, unless the sand is always of exactly uniform composition and quality as regards size, sharpness, surface of grains, degree of dampness, etc., and sand so uniform in quality is difficult to obtain. However, ground quartz can be purchased. This crushed quartz should pass a sieve of 400 meshes per square inch, and should stop on a sieve of 900 meshes per square inch. The practice of testing cement, mixed with crushed quartz, is well enough for a laboratory operation, but it does not give the information so essential in connection with an actual sand. It is not sufficient to know that a particular brand of cement will yield certain results when mixed in various proportions with crushed quartz. The concrete or mortar which is to be used is not composed of a standard sand, but sand obtained in the open market. At the same time, it would be unjust to condemn a cement because it contained an admixture of bad sand. Requirements as to general qualities of sand are found in first-class specifications, but they are sometimes expressed in such indefinite terms as to be of little value.

In the tests for the works of the Forth Bridge, the cement was mixed with three times its weight of sand, which had been passed through a sieve of 400 meshes (20 divisions per lineal inch) and retained upon one of 900 meshes to the square inch (30 divisions per lineal inch). About 10 per cent. of water was used in making the mortar. The briquettes were immersed in water after 24 hours for 25 days, when they were required to bear a stress of not less than 170 lb. per square inch. The briquettes of cement in sand are made in a similar manner to the neat cement.

About 1 lb. of cement and 3 lb. of standard sand will make ten of the 1 in. briquettes. The briquettes are treated like those made with neat cement, except that they should not be removed from the moulds until at least 48 hours after they are made. If this test is included in the specification it is usual to specify that the breaking weight should not be less than 200 lb. per square inch, after 28 days from guaging.

The following table indicates the tensile strength per square inch of Portland Cement mortars as compared with the same class of cement neat as tested by the author :—

Age and time immersed.	Proportion of clean sand to cement.					
	Neat Cement.	1 to 1	2 to 1	3 to 1	4 to 1	5 to 1
1 week ..	440	140	66	49	17	6
1 month ..	676	328	189	98	62	42
3 months ..	680	530	447	284	149	98
6 months ..	—	645	483	305	250	197

The superiority of fineness to strength is fully shown from the data given by Mr. Grant:—

Age of Briquette.	Neat.		Three of Sand.		Five of Sand.	
	10·2 per cent. residue on a sieve of 2,580 meshes per sq. inch.	Sifted so as to pass all through sieve of 32,257 meshes per sq. inch.	10·2 per cent. left on sieve of 2,580 meshes per sq. inch.	All passed through sieve of 32,257 meshes per sq. inch.	10·2 per cent. left on sieve of 2,580 meshes per sq. inch.	All passed through sieve of 32,257 meshes per sq. inch.
Weeks.	lb. per sq. inch.	lb. per sq. inch.	lb. per sq. inch.	lb. per sq. inch.	lb. per sq. inch.	lb. per sq. inch.
1	353	346	75	252	31	136
4	533	380	171	330	97	208
8	585	469	206	358	118	223
25	710	495	282	397	166	272

(6) *Test for Soundness or Constancy of Volume in Setting.*— No matter how excellent a cement may appear to be in other respects it is imperative that it be not used if it is unsound. Soundness being the chief point in the cement, it follows that the first test should be in this direction.

The temperature of air and water and the quantity of water affect the time of setting. Specifications as a general rule contemplate a temperature varying not more than from 10 to 62° F., and the quantity of water for Portland cements is 20 per cent.

The test is carried out as follows:—Mix thoroughly for not less than five minutes, time to be estimated from moment of adding water. Make on the slabs (preferably ground glass) two cakes from the mixture about 3 in. in diameter, $1\frac{1}{2}$ in. thick at middle, and drawn to thin edges and cover them with a damp cloth or place away from currents of dry air. At the end of the time specified for initial set apply the needle one twelfth of an inch diameter weighted to $\frac{1}{4}$ lb. to one of the cakes. If an indentation is made the cement passes the requirement for initial setting, if no

such indentation is made by the needle it is too quick setting. At the end of the time specified for final set apply the needle one twenty-fourth of an inch diameter, loaded to 1 lb. The cement cake should not be indented.

Expose the two cakes to air under a damp cloth for 24 hours, place one of the cakes, still attached to its plate in water for 28 days; the other cake immerse in water at about 70° F supported in a rack above the bottom of the receptacle ; raise the water gradually to boiling point and maintain this temperature for six hours. Then let it cool. Examine the cakes at the proper time for evidences of expansion and distortion. In the event of the boiled cake becoming detached from the plate by bursting and warping, or showing expansion cracks, the cement may be rejected, or it may await the result of 28 days in water. If the fresh water cake shows no signs of swelling, the cement may be used in ordinary work in air or fresh water for lean mixtures. If expansion or distortion cracks are shown on the fresh water cake, the cement should be rejected. Of two or more cements offered, all of which will stand the fresh water cake test for soundness, the cements that will stand the boiling tests also are to be preferred. For natural cements the test for soundness may be dispensed with.

(7) *Test for Coolness.*—In some cases cement which appears perfectly good in every way, has a tendency to crack and swell when placed under water. This action—commonly known as "blowing"—is caused by the cement being under burnt by its containing an excess of lime, and by its not being properly "cool," that is, free from unslacked particles. To detect this tendency to "blow" it will show signs of expansion after a day or two under water ; in extreme cases the samples will entirely break up, but a few cracks about the edges are the commonest indication.

Pats should also be made about 3 in. in diameter and $\frac{1}{2}$ in. thick, gauged in neat cement, with thin edges, and placed upon pieces of glass or other non-porous material.

One is placed under water and watched ; if 24 hours after its immersion there are no fine cracks about the edges, the cement may be considered safe.

With slow setting cements, surface cracks commencing at the centre are merely the result of the surface drying too rapidly.

The other pat is left in the air, and should remain of a dark grey colour. If it is yellow or ochrey the cement contains too much clay, and it is likely to be deficient in tensile strength.

Miscellaneous Tests.

(1) Cement mixed with water to about the consistency of treacle is poured into a bottle, such as a medicine bottle, and shaken until it overflows. If the cement is over-limed or even

if the proper grinding and amalgamation of the raw material has not been made, the cement in the bottle, will, after a time split the bottle. If, on the other hand the cement is under limed the cement in the bottle will contract and become loose in it. This shrinkage is not so bad a fault as the expansion of it, from over-liming, but for all that it is most undesirable seeing that it is a sign of weak cement, and as a rule is of a bad colour.

(2) There is another easy test for this as follows:—Cement is mixed with water, but instead of placing it in a bottle it is put on a piece of thin sheet iron, which in turn is placed upon a fire or somewhere where the water can be quickly evaporated from it, care being taken not to have it hot enough to boil the water out. If the cement is a sound one it will remain solid and harden to a certain extent, but if over-limed, or badly mixed, it will crack more or less according to how bad it is.

(3) Another simple test is to gauge up a little cement to a very stiff paste and put it in the form of a pat, with its surface smoothed, upon some non-absorbent material, such as glass or slate. This should be allowed to set in air, after which a very good idea may be obtained as to its soundness by dipping the finger in water and passing it quickly over the pat in such a way as to leave some water on it. If the cement is over-limed the water will be absorbed instantly; if it is about right it will disappear gradually, taking, say, from 3 to 6 seconds, and if under-limed, will take a correspondingly longer time. This pat may then, in order to obtain a more definite proof as to its soundness, be placed in water, where if overlimed the pat will crack, and if bad enough, fall to pieces.

(4) *Chemical Tests.*—The importance of having a chemical test for Portland cement, in addition to the other tests, has lately been strongly recommended in consequence of failures arising from an excess of magnesia which has slaked and expanded in the work, causing rupture; an excess of lime may have the same effect or cause weakness; more than 2 per cent. of magnesia or 1½ per cent. of sulphuric acid is said to be injurious to Portland cement.

(5) *Microscopical Tests.*—These tests are sometimes used for determining adulteration, as the residue on sieving the cement will present a very different appearance under the microscope from that of a good cement. If the adulterated matter has been extremely finely ground this test is of little use.

Adulteration of Portland Cement.

It is stated by some manufacturers that iron slag is used for the adulteration of Portland cement. If this is suspected the only way to avoid it is to refuse to accept cement from any manufacturer who has slag on his premises. Slag has been refused both for cement making and as an aggregate for concrete,

for fear lest the lime which it contains should disintegrate after use in the work. Slag properly treated by being burnt with lime is, however, sometimes used as the basis of a good Portland cement.

The Engineering Standard Committee has issued a Standard specification.

The writer has endeavoured to call attention to a question which he considers to be of considerable importance, but which is very complex, and he sincerely trusts that the members will be able to throw still more light on the whole subject.

COMMENTS BY MR. HERBERT W. ANDERSON (LONDON) ON MR. BELLAMY'S PAPER.

I have not been to Queensland myself yet, but I have to many other parts of the world in my 25 years' experience in cement, and I have noted the behaviour of the article in all sorts of climates, and compared notes with the condition in which it left the makers works in this country.

It is rather difficult for a paper of much value to be read on this subject unless one is *thoroughly* au-courant with the manufacture.

Many people think that by going over a maker's works a few times they have got the hang of the whole thing, and with the aid of various papers like this, and text books and newspapers that have been and are published almost ad-nauseam on this subject, they have the belief that they have a very complete knowledge of cement, and can draw up a specification embracing all the leading desirable points, proving once again that a "little knowledge is a dangerous thing." The more one gets to know about cement the less they find they know.

As an example might be quoted, the man who specifies a very fine grind and a heavy weight per bushel, both excellent in a way but relative to each other. Few appreciate the finer the grind the quicker the set is likely to be, and also the higher temperature on gauging, and they think they get a sound cement by specifying a limit to the rise of temperature like the absurd "marmalade pot" test.

Another amusing instance is when an engineer to an important railway in the Colonies in making a contract for many thousands of barrels specified 15 % on a 2,500 sieve. The maker who obtained the contract said "will the engineer pass no per cent. on

a 50 and 2 % only on a 5,776 sieve, as his machinery could not make such coarse stuff, and although his order was large enough to alter it, the maker would prefer not doing so, but would without extra cost, supply the much finer grade. The reply was "No, do as you are told and contracted for, I have bought 15 % on 50, and I mean to get it." It was evidently considered that the maker was a bad lot, and was trying to beat the buyer.

The fads and enormous variety of the numerous specifications called for by engineers is most confusing and difficult and expensive to conveniently supply, as one man's meat in many of them is another man's poison. It is hoped the standard specification, when issued, will be honestly and universally adopted, and thus remove this perplexity and bar to the true progress of the cement trade.

A book was published by a man of world wide reputation on cement in Paris last year in which he stated in the preface that one of the causes of the slow progress in the lime and cement industry in the past was through tying the maker down to the terms of this and that specification, or even the Government one.

The standard specification will be issued this month, and it is to be hoped that this complaint will not lie against this as being a stumbling block to cement progress in this country. The terms of that specification I have seen, and it is really very moderate in its clauses, and, to my mind, might have been with advantage in some points made slightly more stringent, but as it is advisable "to run before we can leap," it is probably advisable to test the working of the clauses as they will be issued, and then at some later date revise it in the points where it is found desirable to do so, or if necessary issue more exact descriptions of the standard ways of making the various tests on absolutely standard lines.

The strengths that the author mentions as being high at 48 hours are really nothing abnormal, and now are reached frequently by the better brands of English manufacturers, in fact some of them, and one in particular, approach regularly 900 lbs. and over to the inch at seven days, and the cement so made is absolutely sound in every way, standing the glass tube test, boiling test, and the Le Chatelier test, as well, of course, all the old fashioned minor pat and steam tests which it is quite unnecessary to carry out if you are specifying the more severe tests just mentioned.

These cements also show a progressive increase in strength throughout, and the firm in question have tests over some years of this quality without showing a single falling off of any of their tests as time went on.

The author says one reason for the large demand for foreign cements is their quick setting properties. It is quite easy, if he only asked for it, to get a quick setting cement to equal any foreign production. The tendency as a rule is to get a cement

slow enough to meet usual requirements on arrival in warm climates.

Too much stress must not be laid on makers intentionally placing on the market an underburnt article, very few of them indeed limit the fuel used, although some makers are certainly less careful than others in *picking out* any underburnt particles. The present system of washing, proving and blending the samples in the raw state, so as to get a perfectly homogeneous mixture, as well as the extremely fine grinding after the clinker stage, makes it possible to get a safe cement much higher in lime than hitherto, and also one that will easily and rapidly purge itself if any free lime should accidently fail now and again to be picked out after leaving the kilns.

Makers who have made a speciality of producing very finely ground cement, far in excess of the proposed standard specification, are aware of the great damage that is caused to their products by the so called "aeration" of the cement on the job before it is used. Every day it is kept spread out, in the form described and recommended by the author, absolutely spoils the cement, and cement made to such a quality is absolutely fit for use, and the better for use, as soon as it leaves the maker's works.

If a cement will stand the boiling test, glass tube test, and the Le Chatelier test, or even the latter alone will be sufficient as the other two tests mentioned must be satisfactory to pass this, it is impossible for the cement to give any deleterious result on the work.

The Associated Portland Cement Manufacturers, I understand, have introduced into several of their extensive factories in this country a method of hydrating the cement and so avoiding the use of gypsum.

Most of the Continental makers of highest repute, and also probably all the American manufacturers, attempt this same object by watering the clinker after it leaves the kiln.

It is a pity the author, in quoting the statistics of the United States, did not give the figures (if they are of any value to us at all) brought up-to-date, instead of leaving off six years back. He would find the six years since 1898 would indicate a far greater progress in favour of the rotary kiln over other kilns.

The author advises that the *analysis of the slurry* should be carried out "daily" by the manufacturer, it is more frequently hourly that such tests are made and further than this, in the better works, they run the slurry into large proving or else averaging tanks so as to ensure a uniform article, chemists carefully controlling the mix continually throughout the night and day.

The author might have mentioned under the dry process that it is not always necessary to put the material into a pug

mill and make it into bricks. The cost of making these bricks, drying, and stacking into kilns, frequently far outweighs the saving of the fuel concerned. Most American works and several European ones are on dry process, and calcine the raw powder direct.

The manufacturer, in order to be able to handle "Rotary" clinker, or even the ordinary material of the required fineness of the present day at such a cost as to be able to sell his product, and leave a moderate profit for himself, long ago gave up the use of "stones," this type of machinery being far too costly for power and labour to be of any use whatever.

For many years past, other types of mills have been in vogue almost too numerous to mention, such as the Ball and tube mill, horizontal rolls, edge runners, Griffin mills, Kent mills, etc., all taking very much less labour and power than stones, and being able to reduce the hardest clinker to extreme fineness.

A remark is made that "preference should be given to a testing machine which applies the load at the rate of 400 lbs. per minute." I do not know why this should be stated, as I do not know of any machine that is not capable of adjustment in this direction of speed. In France it is customary to specify an equivalent of 852 lbs. per minute, In Germany 427 lbs. per minute, while in England up to now, and also in America, the speed has generally been 400 lbs per minute, but the new specification has a slightly increased speed to this.

The speed of breaking, as the author says, has a very considerable effect on the stress that can be put on the cement, and should be carefully defined and observed.

As regards the specific gravity test, the objection to the bottle mentioned by the author, is that when a large number of tests have to be made it is rather troublesome to get rapidly cleaned, and for continual work, where a large number of s.g. tests have to be made, nothing beats the s.g. flask mentioned in No. 3053 in Griffin's list. It enables as much as 150 grammes to be tested at one time instead of 50 or 100, thus minimising the error this test is so liable to give. It also permits of rapid cleaning, the neck being of as large a diameter as is compatible with the scale that has to be put on it.

The author ought to have given the caution, that it is necessary to ensure the exact temperature being maintained throughout the period of the experiment.

The sieve of 2,500 mesh mentioned by the author is a rather out of date one at the present day. Again, the "correct gauge" that he mentions for the wire is not correct, it should be No. 37 Standard wire gauge instead of No. 39. The size of the wire being ·0068" and the size of the hole ·0132". The better sieve to use is nothing coarser than a 32,400. With very fine cements, or other material, there is great trouble from clogging

up such fine meshes, owing to the rapid absorption by the material of the moisture from the atmosphere, and the only way to keep a clean mesh is by occasionally warming the sieve over a lamp to bring life again into the particles.

It is quite sufficient to take 100 grammes for determining the percentage of fineness. It is absurd to think of taking heavier weights like a lb. or more when dealing with such fine sieves, as the weight of the material soon damages such delicate gauze and can only give the same proportionate results, as correctly obtained test samples of 100 grammes would, when properly treated, on a 7″ diameter circular sieve.

Some other handy ways, other than the tricky, bulky, and troublesome machine mentioned by the author, may some day be devised for testing the fineness, but this item of examination ought to be easy to avoid making, if other requirements in the specification are made to ensure a suitable cement being supplied to the purchaser, and the fineness test omitted by the purchaser. It is only a side issue test to get certain results in quality and really only a manufacturer's test, the quality sought being controlled by other tests in the specification.

With regard to the time of setting, this is one of the main points of trouble as to when the complete set is defined by the mark of the needle, it is a pity various countries should not have a more uniform test for defining the setting.

The French Vicat needle works out to a stress of 427 lbs. per square inch pressure on the point. The English needle gives a pressure of 640 lbs., while in the United States the Gillmore needle for the initial set gives 46 lbs. per square inch, and for the final set 734 lbs. per square inch.

With regard to the tests of strength it is a pity for many things that the compression strength is not better known, but if it were it would certainly be necessary to have a very definite or standard way of applying the pressure and of making the cubes, and also an absolutely standard size of cube.

I have made tests on cubes varying in size from 2″ up to 12″ and they give really very varying results, although the base area of a cube is always in the same ratio to the height.

The difference in results arises mainly, no doubt, according to the way the moulds are filled, as it is impossible to fill them all with the same efficiency as the size increases, and the speeds of applying the load also requires alteration in relation to the area operated on.

The neatest machine and the one liable to give the least error, I think, is the hydraulic one of Amsler-Laffon.

I am not at all sure that the Compression test is always in the proportion stated by the author, compared with the tensile one.

With regard to *preparing the neat test* I do not agree that the percentage of water should be specified, as it is only natural that

a cement carrying a higher percentage of flour than other cements, and thus having more cementitious particles to hydrate, requires more water to gauge it. A cement containing over, say 75% to 80% flour by Flourometer would be very difficult to gauge neat with 20% of water, anyway in this country.

With regard to the *duration of tests*, it is the custom of the better manufacturers at regular intervals to make up sets of tests extending up to, in some cases, as much as 20 years, and thus they are able to determine what is the most desirable mixture to ensure the progressive or good behaviour in the future.

Neat tests I should very much like to see abolished as quite unnecessary, because there is a tendency to so called intermolecular friction setting up and greater variety in gauging, especially with quick setting neat cements.

Again, coarsely ground cements will frequently give higher results when tested neat than when much finer ground, as has been proved over and over again by many authorities, in spite of the best of cement in the coarser ground being in the shape of residue, which is practically inert.

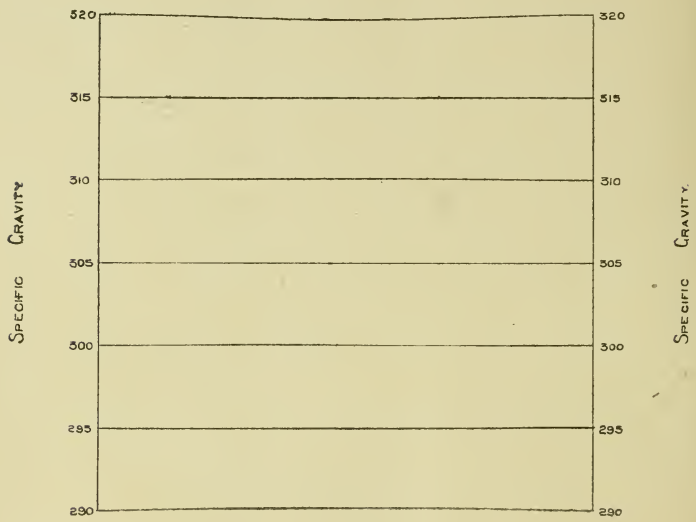
Tests with sand are therefore far more reliable, although of course there is the great objection and risk of obtaining the correct article, which was evidenced in a remarkable way in the early days of the Forth Bridge quoted by the author, and when the writer had to investigate the matter.

The sand tests mentioned by the author are exceedingly low for the present high class cements now obtainable.

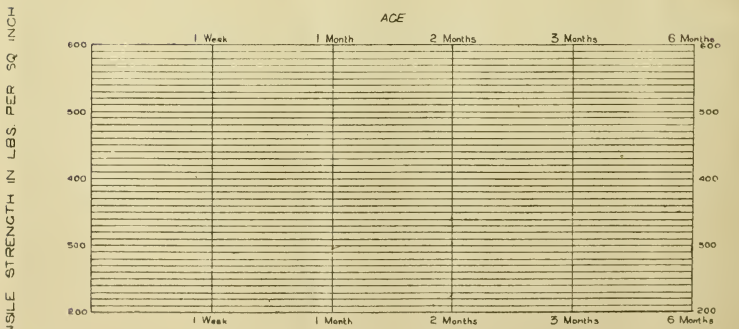
It is quite unnecessary to make any further tests for soundness other than the Chatelier tests previously mentioned.

CEMENT

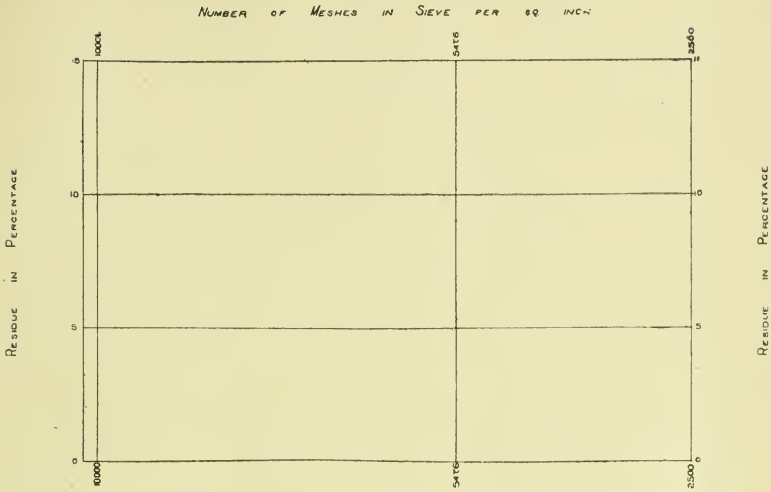
SPECIFIC GRAVITY DIAGRAM



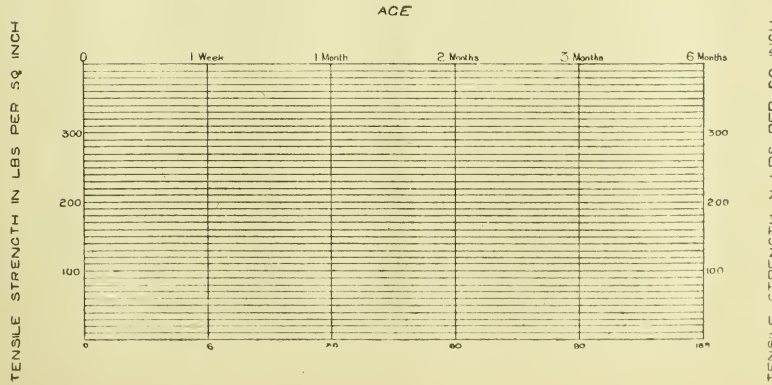
NEAT CEMENT TESTS



CEMENT SIFTING DIAGRAM



CEMENT MORTAR 3 TO 1



THAMES BARRAGE.

By James Casey, M.I.N.A.

[Read before the Society on Thursday, 5th January, 1905.]

In accepting the honour of an invitation from the Civil and Mechanical Engineers' Society, I may say that I feel I have received a compliment that entails upon me, as the author of the Thames Barrage Scheme, the task of placing before you my reasons for promoting the adoption of the project. In my opinion, this scheme offers a solution of the complicated problem of attempting to remove the difficulties and inconveniences attending the navigation of the Thames, owing to the increasing size of steam vessels, and in properly controlling the enormous volume of commerce flowing into and out of the Port. It would also afford a harbour capable of holding the entire British fleet afloat, at all times, and so far as facilities are on the spot, enable it to be ready for action, leaving nothing to chance, or risk of delay. In my opinion, we have an asset in the River Thames, within the heart of the Empire, that few appreciate, provided with an Arsenal at Woolwich for guns, ammunition and every class of war material necessary, adjoining which are the Commissiarat Depôts at Deptford for victualling the fleet, and last but not least the means of coaling the war vessels afloat, with our invaluable smokeless Welsh coal, in war time worth its weight in gold, which can be run direct through the Severn Tunnel to the Thames in a few hours without risk. Again, in case of war with Germany or other power, our ships could get to or from sea in the shortest possible time, there being no harbour of defence for our battleships to enter or use as a base for a distance of about 400 miles along our coasts, after leaving Portsmouth and passing through the Straits of Dover.

The tidal portion of the River Thames proper, extending from Gravesend to Teddington, is 33 miles in length in a direct course, but owing to the various bends and windings in the upper and middle reaches, is about 46 miles in length, a difference of 13 miles. The width of the River at Gravesend—and here it is proposed the barrage should be—is about 2,400 ft., with a depth at low water of 45 ft. The width of the River at London Bridge is 650 ft. at low water with a depth of 10 ft., and the width of the River at Teddington is 250 ft. with a depth at low water of

about 6 ft. The average width of the River between Gravesend and Teddington is about one-third of a mile, and the current about four knots, the rise of tide being from 15 ft. to 20 ft. 9 in. at Gravesend, and 17 ft. to 21 ft. at London Bridge, the fall of the River bed from below Teddington is about 1 ft. in the mile, and without rapid currents.

I can safely say that I have more than a cursory knowledge of the Thames, having been the Assistant Superintending Engineer to the Iron Steam Boat Company, of Nine Elms, and in co-operation with the Citizen Steam Boat Company, I also controlled the Saloon Boats *Alexandra* and *Palmerston*, the first of their class running to Gravesend and the Nore. I think it may be of interest to bring before you the various limits of navigable depths at low water spring tides from Gravesend to London Bridge, as the river is at present. From Gravesend to Crayfordness the limit is 26 ft. draft at low water spring tides, and from Crayfordness to Halfway Reach the limit is 20 ft. From Halfway Reach to Surrey Commercial Docks (eastern end) is 15 ft., and to London Bridge under 10 ft. From this 15 ft. limit the Royal Commission proposed dredging the river to a depth of 30 ft. at low water spring tides down to Gravesend. I will deal with the depths of water below Gravesend and estuary directly. A Commission of Inquiry was held as far back as 1894, on which Mr. (now Sir) John Wolfe Barry sat, but fortunately up to the present the recommendations have remained a dead letter.

I now come to the proposal for constructing a barrage across the River from Gravesend to Tilbury, of solid concrete with granite facings, provided with four locks, two of which are to be 1,000 ft. in length, and two of 800 ft., and 100 ft. and 80 ft. in width respectively, provided with internal steel gates dividing them into lengths of 300 ft. and 700 ft. in the case of the larger locks, and 300 ft. and 500 ft. in the case of the lesser ones. In addition to the outer gates, a number of adjustable steel sluices will also be provided, fitted at the top and bottom of the barrage, and having sufficient area to regulate the flow and necessary scour of the river bottom during ebb tide. In the base of the barrage would be constructed a railway tunnel connecting Kent and Essex with the Northern lines, which, from a commercial and stragetic point of view, would be most valuable. At present all passenger, goods and luggage traffic to and from the Continent has to pass through London, there being no alternative route, but if this railway connection were made, the traffic passing between the Continent and the Eastern and Midland Counties and Scotland would pass directly through without change of carriage, or touching London. This factor should be worthy of consideration by the Royal Commission, consisting of Sir J. Wolfe Barry and Sir B. Baker, who are now considering the best means of relieving London of its congested vehicular traffic, in which inquiry they

have been assisted by Mr. B. Parsons, an Engineer from the United States. I have no doubt the advice tendered to H.M. Government to invite this gentleman over to London was fully warranted, but if my proposal had been put before the Commissioners it would no doubt have relieved them of their anxiety and would have simplified the inquiry, and at least have modified the enormous demands for further outlays upon the ratepayers of London. As to the stragetic value of the tunnel railway, I cannot do better than point out that it would be about 12 miles from Woolwich Arsenal on the west side, and 7·5 miles from Chatham, our Great Naval Dockyard on the east side, thus affording direct and speedy means for the prompt shipment of men and material from these respective depôts. At present, stores have to be shipped by barge, with the risk of delay and loss, or sent through London with its congested traffic. In the case of vessels loading war material at Tilbury Dock for India and the East, trucks laden at Woolwich could be run alongside the vessels in less than an hour. Over the barrage it is proposed to have a roadway for vehicular traffic, and the locks would be worked electrically from a dynamo station. A pilot tower, from which the traffic could be regulated, and the locks and movable bridge controlled, also forms part of the scheme.

The number of vessels passing in and out of the Port at Gravesend during the year, ending June, 1903, was 49,545, but the number of small craft, barges, tugs, etc., of 45 tons register and less is stated to be about 3,420 per week, or about 20 in the hour. The four proposed locks working 24 hours per day, would be capable of passing 396 ships, and 2,628 barges and small craft in one day. There being a level twice in the 24 hours, and special provision made for passing in and out by the aid of Motor Capstans and kindred appliances. On completion the barrage would hold up a volume of fresh water from Gravesend to Teddington equal to 4,860 million cubic feet. The daily flow over the weir at Teddington, *i.e.*, the average total daily supply of fresh water, exclusive of the water taken by the London Water Companys, averages 113 million cubic feet, independent of the additional effluents from the River Lea and Essex streams, of streams on the south bank, and of sewage effluents from Barking and Crossness and storm overflows, taking everything into consideration is equal to 202 million cubic feet, and taking the value of the river at 4,860 million cubic feet, the daily discharge will at least be about one twenty-fourth with a steady downward flow of about a mile to a mile-and-a-half per day always running seaward.

The cost of construction of the Barrage, Tunnel and Auxiliary Works, is estimated at £4,100,360, and the time required for completion, three years, so that having regard to the magnitude of the work, the amount is not unreasonable in comparison with

the purchase of docks, creating new ones, dredging extending over 10 years in the river, at a proposed combined outlay of £37,000,000.

In connection with the dredging scheme, it must be borne in mind, that there is a probability of the wharves giving way, as recently occured at Barking, and at the Port of Boulogue. At the latter place the dredging undertaken with the view of enabling the cross Channel steamers from Folkestone to get in at low water has caused several hundred yards of quay to sink some feet, and the masonry to crack through from top to bottom. The French engineers are excavating behind the masonry in the hope of getting a new foundation, but it is landing them in great expense, of which they have probably not seen the end. If the London County Council were to send a representative to inspect the quays at Boulogue, I think after seeing the damage and the cost of making it good, they would not care to ask Parliament to allow them to dredge the Thames.

The possibilities of the barrage as a storage reservior of fresh water must not be lost sight of. It will contain nearly a year's supply even at the estimated requirements of 1941, and the fact that the new storage reservoirs constructed at Staines and other places are nearly all by some oversight built outside the line of fortifications for the defence of London, gives additional value to the barrage scheme. It is only during the months of August and September as a rule, and then for a short period, the supply, including the water drawn by the companies, is below the 66 million cubic feet passing over the weir daily, but as the Thames and Severn canal has been opened for through traffic recently, after being practically derelict for years, I need not tell you that it would not be a difficult feat of engineering to tap the Severn River, and thus have an additional supply, that so far as London is concerned would settle the water question without going to Wales or some other source at an estimated cost of £24,000,000 as proposed by the London County Council.

The sewage question has been mentioned as an objection to the scheme. I must here state there is a tendency to speak in exaggerated terms with regard to the insanitary state of the River Thames. The scheme recommended in 1884 by H. J. Bazlegette, Civil Engineer to the Metropolitan Board of Works, provided for the extension of the present sewers at a cost of £9,400,000, with two additional pumping stations equivalent to an annual outlay of £80,000 per annum. Upon seeing this report I wrote to the Board, and proposed an alternative scheme at a nominal cost, and which if adopted would, in my opinion, have carried out the work more satisfactorily. I submitted that I would design special sea-going steamers, suitable to the light specific gravity of the sludge, capable of discharging the sludge 15 ft. below the surface of the sea, at a distance of 65 miles

from Barking. I forwarded models and drawings complete to the Board at their request, and they eventually carried out my scheme in principle, but deposited the sludge into one of the best of the channels in the Estuary, namely, the Barrow. Owing to recent complaints and public protests to the London County Council, the successors to the Board of Works, the sludge is now being discharged where I proposed 19 years ago. The Council have six steamers of 1,000 tons each, engaged in preventing the fouling of the river with an annual discharge of about two million tons of sludge, inasmuch as fish are now in the river, it may be concluded that the effluent from the sludge having been treated by the formulae of Drs. Duprè and Odling, passes into the river almost innocuous. Mr. Dibdin, F.C.I., late Chemist to the Board of Works, and also to the London County Council, has thus written :—" The present position of the sewage question is so much advanced that there can be no reasonable objection to the scheme on this account," which confirms my views when dealing with this all-important question ; and those that remember the insanitary state of the River Thames up to 1885-6 must recognise this.

When the River is held up by the barrage, the present unsightly mud banks will be covered, the proposed new steamboat service will give an impetus to pleasure traffic, facilities will be afforded for business and travel, and it will be possible to develope the large areas of sloblands lying idle on both sides of the River below the level of Trinity high water mark, between Woolwich and Gravesend. The barrage will prevent flooding from the sea; pumping arrangements are now being installed by the London County Council on both sides of the River, for draining and preventing overflow. I do not suppose that there were worse districts than the Isle of Dogs on the north side, and Blackwall Point, East Greenwich, on the south side up to 1870 for marsh lands. When that eminent engineer and shipbuilder, Mr. John Scott Russell, was in business at the former place, he had, owing to the surface flood water to contruct a large iron watertight tank at the works, in which he formed a foundry pit to insure safety in making his castings. At times it was a difficult matter to cross the island from east to west, owing to the shallow surface storm waters, but since a pumping station has been installed, docks and works constructed, the character of the district has been much improved from a sanitary point of view.

In 1870, some friends of mine, shipbuilders, bought a piece of land at Blackwall Point, East Greenwich, and constructed a dry dock 475 ft. in length, the largest dry dock on the River at that time ; the ground was literally a mud bank. The Gas Company subsequently erected in the district a huge gasometer, and in pumping to get in the foundations drained the whole district, and where it was once impossible to erect workmen's

dwellings, there is now an inhabited town below Trinity high water level. I cite these cases that have come under my notice in response to the queries as to difficulty in draining the lands below the level of high water. When drained, the land can be utilised for industrial purposes, with river side frontages, and relieve the congested districts of East London.

Below Gravesend, it is necessary that a channel of 30 ft. to 32 ft. in depth at low water spring tides should be obtained to the Nore. At present vessels drawing from 24 ft. to 25 ft. cannot get to Gravesend through the present channel at low water without running the risk of grounding. Consequently they prefer to anchor and come up with a rising tide. At Gravesend there is 40 ft. to 45 ft. at low water, and at the Ooze deep (to the east of the Nore Light Ship) there is 50 ft. at low water. Thus it would not be a difficult matter to secure by mechanical means a through channel waterway. But to place training walls on the north side from Canvey Island would, as suggested by the 1894 Commission, be a great mistake, because we have in this district, within an area of a few miles, some important factors that regulate the ebb and flow of the tides. On the north side Canvey Island, with its creeks; on the south side the Isle of Grain, with its creeks, and the mouth of the River Medway. At the Nore the ebb tide coming down from Gravesend is about spent, and the sand and mud in suspension are deposited; the same may be said with regard to the creeks, and finally with regard to the Medway. Thus there is a confluence of tides and cross currents at the Nore, all enfeebled, and consequently sand banks occur. In the estuary the entrance to the Swin Channel, too narrow at present, has, owing to its proximity to the shore, the upper current running in an opposite direction to the lower one, so that vessels in ballast using this Channel to and from the north, do not answer their helm, and consequently there are more collisions and wrecks in this Channel than in all the others. Therefore the Barrow Channel, which is both wide and deep, should be utilised. As to the suggestion that a direct straight channel might be made from the Nore to the Alexandra Channel, it could certainly be done, but as to maintaining it, I have great doubts, and therefore agree with many that the Edinburgh Channel, although some miles longer, is safer, and not so liable to silt up, being protected from the North Sea by the Long sand. The sand banks throughout the estuary are very much affected by atmospheric changes. A north or east wind will harden a sand to 12 ft. below the surface of the water, but a change to west or west-north-west will set it alive, or make it what our chart compilers designate as a "shivering sand." That is my experience, having many years been engaged in salvage operations in many of the rivers at home and abroad. So far as the lower reaches in the Thames are concerned, I am

sure that if jetties are put down in a tidal waterway the river will silt up.

I look upon the erection of the barrage at Gravesend as a solution of the Suez Canal question, and the onerous charges made upon our shipping by the Canal authorities which are now agitating the British shipowners. The greatest depth of water at present through the Suez Canal is 26 ft. 3 in. When the barrage is erected, and 30 ft. draught of water provided, which will be 3 ft. 9 in. in excess of the Canal limit, this will represent an increased displacement of not less than an additional 3,600 tons or about 7,200 dead weight on the round voyage.

The shipowners, by supporting the barrage scheme, would be in an enviable position financially, compared with the present situation. When it is considered that the imports of grain from India for the past eleven months exceed one million one hundred and thirty-seven thousand tons per month, it is not in my opinion imperative or condusive to shipowners interests that such homogenous coarse cargoes of grain, seed, and cotton should pass through the Canal, at a cost, as stated by some well known shipowners, of 11s. 3d. per ton on the nett register of their steamers, equal to the charges made to subsidise mail steamers, parcel post and passenger vessels carrying high-class freights. I do not think the shipowners, however much they agitate, can succeed in getting a second competitive canal, but by utilising the *Cape route*, in conjunction with the barrage, they could secure profitable freights as against the present route, and at the same time make London the premier port of the Kingdom.

The volume of the water in the estuary is computed to be at high spring tides 70,200 million cubic feet, and at low water 30,500 million cubic feet. What is known as the tidal wave arises from the heaping up of the waters, and as the wave approaches the indented coast line its progress is stopped, and the water being confined into the narrow channels fills up the estuarys and creeks, and in those cases the tide is higher than the open sea. In shallow water such as the North Sea and Channel, the tides seldom exceed 15 ft. rise, and 15 ft. spring tide at the Nore.

The United States Government have for some years past contemplated putting a barrage across the Charles River at Boston, which river is similar in many respects with the Thames, but not so large in volume. After most searching inquiry from an Engineering and Sanitary point of view, they have now decided to erect the barrage, and commenced operations in June last. A special report has been published and issued, which will be found most interesting and instructive.

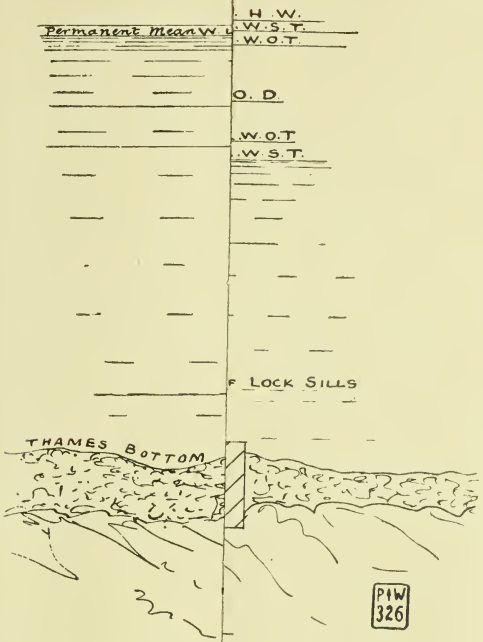
The adoption of the Thames Barrage, as a whole, deserves in my opinion, the most careful and serious consideration of our Naval and Military authorities, to whom alone we have to look for the protection of London, the very heart of the Empire, from

the attacks of any possible enemy. Further, it will add immensely to the prosperity of the Port of London by making it free. The Privy Council could constitute it a Royal Harbour, administered by the Board of Trade, and in every way similar to the Royal Harbour at Ramsgate.

The entire object of this paper I have had the honour of reading to you, is to urge H.M. Government to hold a full and exhaustive inquiry by a Committee, or public enquiry, and the precedent having been established of calling in foreign advice on Vehicular London Traffic—why should not the experts responsible for undertaking the barrage in the Charles River be invited to give their opinions and advice in the case of the Thames Barrage.

The only objection the Government offered to my scheme in the House of Commons, when asked by an honourable member to hold an enquiry on the barrage, was, as stated by the Prime Minister, "That there does not appear to be sufficient expert support for the project in question to justify the inquiry."

I have arranged, with the aid of a small Committee, to re-introduce a Bill in the next Session of Parliament with the object of getting the Government to hold the inquiry referred to, and feel convinced that the great national importance of the project will commend it to the impartial consideration of Civil Engineers generally, and to the members of the Civil and Mechanical Engineers' Society in particular.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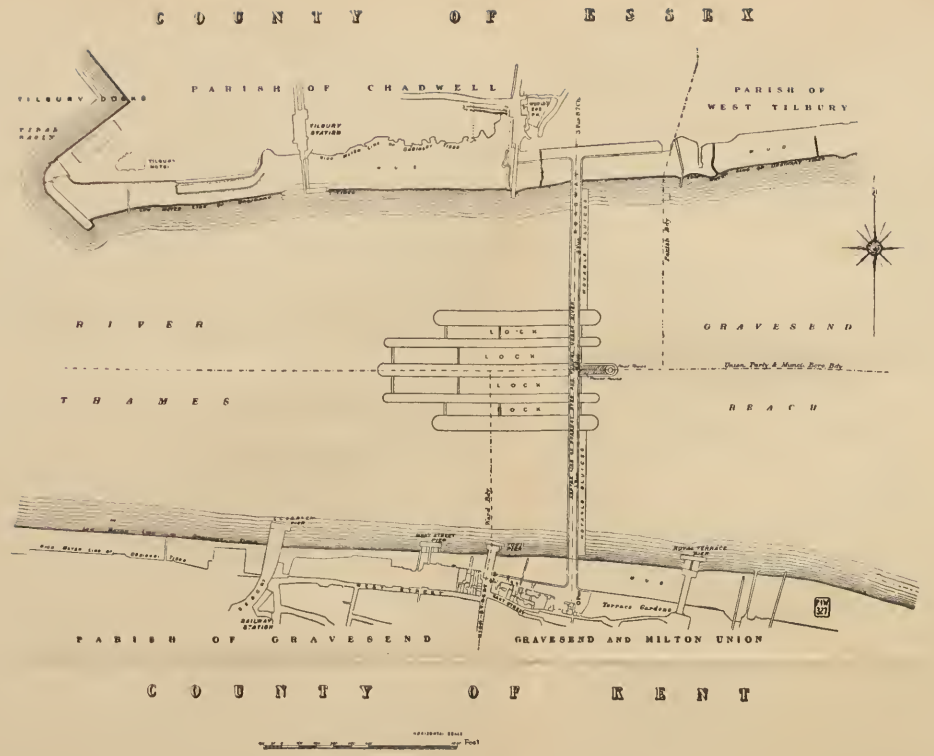
COUNTY OF ESSEX
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GRAVESEND
REACH
Queen, Perry & Mumby Barge Bds
Royal TERRACE PIER
TERRACE GARDENS
RAILWAY STATION
PARISH OF GRAVESEND
GRAVESEND AND MILTON UNION
COUNTY OF KENT
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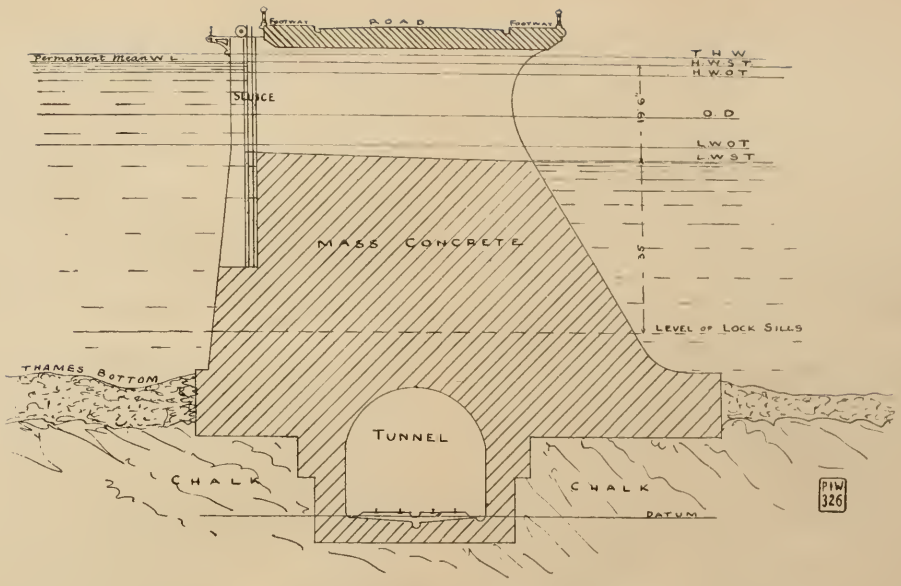
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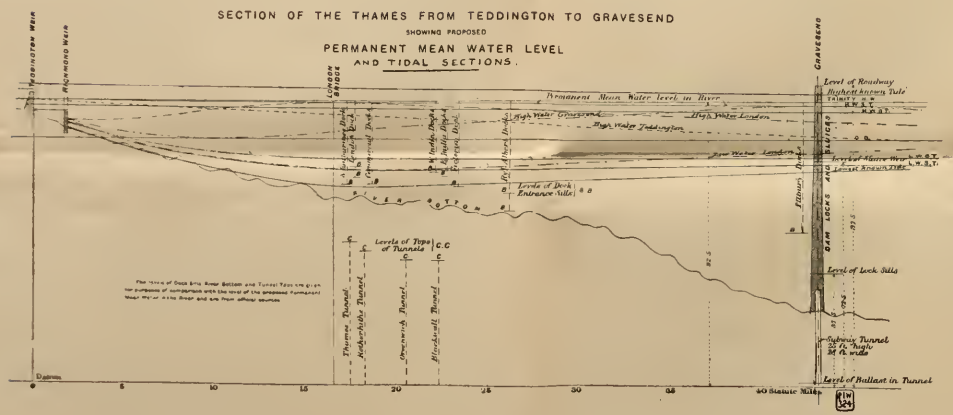
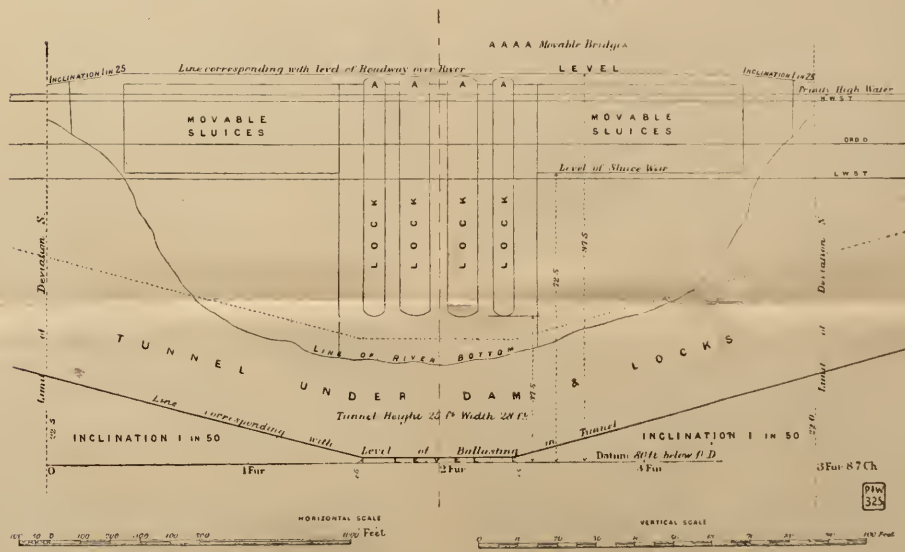

SECTION OF THE THAMES FROM TEDDINGTON TO GRAVESEND
SHOWING PROPOSED
PERMANENT MEAN WATER LEVEL
AND TIDAL SECTIONS.
TEDDINGTON WEIR
RICHMOND WEIR
LONDON BRIDGE
GRAVESEND
Permanent Mean Water level in River
High Water Greenwich
High Water Teddington
High Water London
Low Water London
Level of Roadway Highest known Tide
Level of Sluice Weir
Levels of Dock Entrance Sills
RIVER BOTTOM
DAM LOCKS AND SLUICES
Ebbing Dock
Levels of Tops of Tunnels
Thames Tunnel
Rotherhithe Tunnel
Greenwich Tunnel
Blackwall Tunnel
Level of Lock Sills
Victoria Tunnel 22 ft. Height 14 ft. wide
Level of Ballast in Tunnel
40 Statute Miles


AAAA Movable Bridges
INCLINATION 1 IN 25
Line corresponding with level of Roadway over River
LEVEL
INCLINATION 1 IN 25
Priests High Water
MOVABLE SLUICES
MOVABLE SLUICES
Level of Sluice Weir
LOCK
LOCK
LOCK
LOCK
Line of Deviation
TUNNEL UNDER DAM & LOCKS
LINE OF RIVER BOTTOM
Tunnel Height 22 ft Width 28 ft
Line corresponding with Level of Ballasting in Tunnel
INCLINATION 1 IN 50
INCLINATION 1 IN 50
Datum 80 ft below O.D.
LEVEL
0
1 Fur
2 Fur
3 Fur
4 Fur
3 Fur 87 Ch
PTW 325
HORIZONTAL SCALE
Feet
VERTICAL SCALE

THE MECHANICS OF FLOUR-MILLING.

By A. R. Tattersall.

[Read before the Society on Thursday, February 2nd, 1905.]

Your attention is directed to the interesting study of the art of making flour, the results of which are in everybody's mouth, while the methods adopted during modern times may not be familiar, even to this highly-trained and scientific audience. I purpose therefore after a very brief sketch of the history of wheat grinding, to explain the mechanical principles employed in the production of the flour of modern commerce, including the treatment of the merchant wheat and the granulation, purification, reduction, and sifting, until the complete process is outlined.

The ancient history of flour-milling, or the making of edible food from cereals, we venture to assert, is a most instructive and interesting subject, not merely to those directly engaged in the milling trade, but to the public at large, who one and all partake of their daily bread.

Undoubtedly the earliest efforts of inventive genius must have been in connection with the milling industry; the germs of mechanical skill and ingenuity were here propagated in devising means of preparing food. How simple and rudimentary those efforts were we have the most conclusive proofs.

As the principle of evolution has been applied in these days to all organic life, can we not trace the same process at work in the history of mechanism as applied to milling?

We may start with this important advantage, that we know something fairly conclusive about the "first form" or origin, which we take to be that of one stone pounding or rubbing the grain against another stone, and then one stone—the bottom one—was hollowed out, forming a mortar, while the upper stone was convexed to form a sort of pestle. This simple method was in use for many ages, and was practised by the Romans as lately as the time of Vespasian, A.D. 79, so that the evolution was very slow.

Among the hieroglyphics, on the stones of that most anciently civilised country, Egypt, we find representations of the art of milling grain and sifting the fine meal from the husks or bran by hand sieves which must have been a decided advance on using the crude whole meal. We find also that as far back as the times of Abraham, they had their "extras" and "seconds," as we read that when the angelic visitors appeared unexpectedly to

Abraham he directed that Sarah should "make ready quickly three measures of fine meal, knead it, and make cakes on the hearth." In their hasty exit from Egypt the Israelites probably carried portable mills with them, for when other provisions failed, had they not manna from Heaven, like coriander seed, which had to be ground? (Numbers xi., 7, 8). One of the earliest laws of Moses, indeed, recognised the grinding mill as a requisite to every family life. This law is to the effect that "no man should take the nether or lower millstone to pledge, for he taketh a man's life to pledge." In these early days, as in later ones, women undertook to exploit all the latest inventions, and so ousted the sterner sex out of its privilege of making an honest crust, and constituted herself the motive power, as we find several references in the Scriptures to women grinding at the mill. Indeed, to this day in Syria, and particularly in Palestine, may be seen the two women grinding at the mill.

And so right on for several thousand years at least, the art of milling in the remoter portions of the country has seen no change, but it has been otherwise with Western milling, although, no doubt, these first implements came to us from the East, as we have never heard of anything of the kind having been found amongst the Aborigines of America or Australia to grind the substances used by them as food. The quern, or hand mill, was, however, introduced into Europe, and spread amongst the Britons and Gauls long before their subjugation by the Romans.

Bread of excellent quality, by the way, has been found among the ruins of Pompeii in good preservation, and the methods of milling and baking used in that ancient city have been preserved intact by the fiery flood of Vesuvius.

With the progress of time, water power was applied to do the grinding. Vitruvius, who died 13 B.C., describes water wheels as used for this purpose by the Romans. Public water mills are mentioned in the Roman laws in the year 398, but probably very few then existed. The subjugated Britons adopted these water mills, and they were generally erected at each station. Each pair of mill stones was driven by a separate water wheel. It does not appear to have occurred to any one to erect a large water wheel, and drive several pairs of stones from it, until the middle of the eighteenth century.

During the Roman occupation of this country, commencing in the year 55 B.C., agriculture and many other useful arts, amongst them the manufacture of flour and bread-making, made some progress. The invasion of the Saxons in the fifth century retarded this progress.

White wheaten bread was used by the Anglo-Saxon clergy for sacramental purposes, but was considered so great a luxury that the Saxon kings rarely partook of it. The constant wars prevented much advance in the arts until the reign of King Alfred,

in the ninth century, and the cakes he burned were probably made of barley meal. In Domesday Book hundreds of mills are mentioned, and put down as of considerable value, and as sources of profit to the owner. A large number of these mills are still existing. Very few streams throughout the length and breadth of the land are entirely without their rumbling mills, particularly within wheat-growing areas, and often as many as eight or ten may be found within as many miles, but, alas, owing to the diminishing area devoted to wheat production, and the enormous imports of foreign wheats, huge mills have sprung up at the seaboard, and are manufacturing these foreign wheats into flour, which is railed inland.

The Roman water mill continued as an institution until the beginning of the eighteenth century, but there was little improvement in it mechanically. British records of flour mills are of the most meagre description, but interesting information may be gleaned from the Dutch, French, German and Italian writers, some of whom describe mills much on the lines of the tread mill, where the weight of men stepping up a large wheel, or the "endless staircase," as our prison frequenters term it, gives the requisite motive power. The Dutch, however, whose country sadly lacks water power, were early in harnessing the wind as a cheap motor.

The type of water-wheel almost invariably adopted in this country until the time of Smeaton, the engineer (of Eddystone Lighthouse fame), was the undershot, which meant that the water ran under the wheel, and catching the projecting blades or buckets, forced it round.

The "Dictionary of Arts and Sciences," published in 1763, gives a sketch and description of an *over* shot wheel. This shows the water conducted to the top of the wheel and filling buckets, which, by their weight, forced the wheel to revolve.

John Smeaton introduced many improvements in mill-gearing and driving. It was near the town of Wakefield, in Yorkshire, that Smeaton applied spur-gear under the millstone to drive several pairs at once from the same water-wheel—an entirely new application of this simple device, if I am not mistaken. He was also the first to advise the application of steam engines to drive flour mills, in a letter addressed to the British Government, dated November 23rd, 1781. The Albion Mills, London, were the first steam mills erected, and were situated near Blackfriars Bridge. They were completed in 1788, but were destroyed by fire a few years after. They were looked upon with jealousy as a monoply and injurious to the public, but it is said that these mills reduced the price of flour in London.

Cast-iron wheels and shafting were first introduced in place of wood at this mill; some wooden shafts, both vertical and horizontal, still linger in outlying country mills, and may be

seen under moss-covered roofs and lichen-grown walls, like the trunks of forest trees revolving.

Necessity, is often stated, to be the mother of invention, but who will doubt that laziness also provokes ingenuity. It is said that a boy who used to perform the duty of turning a handle for injecting cold water at each up-stroke of Newcomen's atmospheric engine, made his handle self-regulating by connecting the beam of the engine with a valve, and was forthwith rewarded for his pains by dismissal from his employment, as he was no longer required. So it has been in the case of the development of flour milling mechanics. The man who got tired of lifting the sacks of wheat up over the millstone hopper, hit upon the plan of shooting the wheat down on the floor, and letting it run down into a hole, out of which he made cups or small buckets, attached to an endless band travelling round iron wheels, lift the wheat and elevate it over the millstone to be ground. Mechanical contrivances gradually thrust muscular action out of the field of the industries, cheapen the cost of production, and mark the progress of every system of manufacture. It is a remarkable fact that the broad principles of flour milling have been practically the same from the third to the nineteenth century, viz. :—The upper stone of the pair was made to rotate on a vertical spindle over the nether or lower one; the wheat to be ground was fed in through a hole in the centre of the running stone, when, by reason of the dress or cut, put into the grinding surfaces of the stone, assisted by centrifugal force, the wheat became pulverised on its way to the periphery or skirt of the stones, where it was collected and sacked off. In later days mechanical sifters and dressers, consisting of woven wire-covered cylinders, made to revolve, were utilised for separating the husk of the grain, known as bran. Minor points of advantage were applied in some cases, but it is within the memory of living millers that the above simple method was almost invariably practised. The particular stone used was the Freshwater quartz or Burr stone, from La Ferte sous Jouarre, in the province of Champagne, France. This stone being compact and porous, very hard, but easily worked with the chisel.

The mighty changes effected in textile manufacture by the inventions of Richard Arkwright and Edmund Cartwright do not outshine the brilliancy of the revolution effected in the manufacture of flour during the last 30 years, but the halo of fame and honour surrounding the flour machine inventors can never be ascribed to any one man or group of men, or even to any one country.

Hungary, no doubt, fairly claims the first place in introducing the system of making flour by means of iron rolls instead of by stones, and at the same time insisting upon reducing the wheat in a series of operations instead of by one, as had been the case

from time immemorial. It was argued by the originators of this new process that the wheat, owing to its physical structure, during its passage from the eye of the millstone to the outlet at the skirt, had its skin so far powdered, and this powder mixed with the kernel, that the resultant flour was rendered impure and dark-coloured; moreover, the germ was comminuted and allowed to pass away with the flour, whence a deleterious effect upon the keeping and baking properties of such flour. The new style of milling, to be henceforth called "gradual reduction milling," as opposed to the "sudden death" principle implied in stone milling, struggled on through many initial difficulties in the way of defective mechanism and faulty grinding surfaces, trying porcelain and steel, and eventually adopting chilled-iron rolls, trying the relative advantages of the comparatively few and the superlatively many operations, until it settled down into what the Irishman termed "the middle ixtrame" of four or five stages of the shelling out of the kernel from the husk, called in milling parlance "breaks."

It might probably be asked at this point, if the husk or bran is so detrimental to the flour, why not decorticate the wheat berry first, as barley is pearled or husked? The peculiar crevice which runs longitudinally from end to end of the wheat has hitherto prevented this, and numerous and costly experiments have gone to prove that the grain must be broken up before the husk can be eliminated in a marketable form.

To describe in every detail the complete *modus operandi* of a modern mill would impose an undue strain upon my hearer's patience and attention; hence I propose very briefly to sketch out the main features of the scheme, the objects we aim at, and the course we pursue, and the mechanical appliances in common use.

First of all, our object is to obtain branless flour, and flourless bran, or, in other words, we want all the flour away from the husk, and all the husk away from the flour, to go away as offal for cattle food.

And now for a short run through a modern gradual reduction mill. We enter with the incoming wheat, which is often very dirty, and mixed with extraneous seeds and other matter, all of which must be eliminated.

Sieves and fans to separate and aspirate out such foreign bodies are then applied. Specially indented cylinders take out seeds which differ from the wheat in physical structure. Much of the wheat is washed and scrubbed, and then dried with hot air. After these operations it is scoured again, and brushed and fanned and aspirated until all adhering dirt and admixture is extracted. Then the proper proportions of various wheats are mixed automatically, and the wheat eventually reaches the garner over the grinding section in the mill proper. And just here it should be mentioned that

from its entrance into the warehouse, from boat, or truck, or farmer's waggon, the wheat is not again handled by man, but is moved on by mechanical contrivances, in the shape of elevators, for vertical lifts, worm or band conveyors for horizonal transit, and wood trunks or spouts for inclined passages, where the material falls by gravity from the one machine to another in a lofty building. The entire system is one connected whole, like a single huge machine, all dependent and interdependent on the rest, until finally the original wheat is divided into the various finished products and sacked off for the market, never having been touched by the human hand, except for the purposes of examining and testing the work of the separate machines. One motor gives the necessary motion for this great automatic machine.

Now, to return to the clean wheat we have left in the garner—which, by the way, is part of our programme—so that it may assimilate and become mellow by contact, grain with grain (as constant intercourse is said to assimilate character). We now submit the wheat to the first "break" or grinding, between a pair of fluted chilled-iron rolls. The grain is thus smashed up into several parts, and part of the kernel or epidermis released, and separated by a sieve, called a scalper, the broken wheat tailing over the sieve is again passed through a pair of rolls, having finer flutes and more closely adjusted, and so on to sieve and rolls four or five times, until after the last pair of rolls very little flour or kernel is left adhering to the bran or husk, and this is agitated in a cylinder until all the flour is detached and escapes from the perforated covering of the cylinder, and the bran is overtailed and sacked off.

Now, this kernel of the grain we have released by a succession of operations, is in a granular-shape like semolina, commonly used for making puddings; in fact it is semolina and some little flour mixed with it. This flour is separated, and then the granular stock is graded into several sizes, which are then purified. Now, this process of purification is the great feature around which clusters much of the beautiful and delicate skill attached to modern flour milling. It will be readily understood that in passing through the fluted rolls some of the husk of the bran has been grazed off, and become mixed up in the granular stock, and must be separated. This husk, though found in particles, the same size as the semolina, is of less specific gravity, and is taken off the pure semolina by means of suction fans as it passes down inclined vibrating sieves, covered with silk. The process of purification and re-purification is applied to each grade or size (for there are many) until they are in a proper state for being reduced into flour. This is accomplished by means of smooth surfaced chilled iron rolls, to which pressure is applied by means of levers and springs. Rolling is succeeded by dressing in

cylinders covered with silk, through which the flour made between the rolls is forced, and the rejections or over-tails are subjected to repeated rollings and dressings until all the flour is extracted, and what is, in milling phraseology, called the "finish" or "pollard" is left, and this, consisting of very small particles of bran, and the cellulose (which forms the walls of the starch cells) goes to feed a familiar domestic animal.

What the "Miller of Mansfield" or even poor "Mr. Tulliver" in "The Mill on the Floss," who found the world such a puzzling thing in his time, would have said to this intricacy of manufacture, we scarcely dare venture to speculate, but true it is that the spider, which used to revel in its mealy fly, and so amuse the miller's lovely daughter, would find very uncomfortable quarters here.

You will naturally enquire why all this change and revolution, this ruthless abandonment of the humming millstones, with the familiar rattle of damsel and shoe handed down through ages from hoariest antiquity? What ailed the flour of our youth and our ancestors that it must needs be counted no longer worthy food for sustaining modern activity? Well, the answer is, the demand for whiter, and consequently purer flour, induced the supply. The scientific answer is, better and more nutritious food.

The end and aim, therefore, of the problem of milling wheat may be summed up as follows:—To separate in as simple a manner as possible the interior of the grain from the outer rind, the beard and the germ, to thoroughly grind the cells of which the grain is composed, and by setting free the starch grains from the outer integument in which they are enclosed, to facilitate a quicker and more intimate contact of the nourishing qualities contained in the wheat, with the human alimentary canal.

The old stone system failed to produce the fine white pure flour which has so rapidly sprung into favour, from the simple fact that in its journey from the centre of the stone to the periphery, the pressure of the upper stone (being of sharp gritty texture) upon the lower one, in the attempt to grind all the flour from the wheat, pulverised much of the bran into fine particles, which became irrevocably mixed with the flour, and so discoloured it. The duration of contact and the grinding surfaces were objectionable features.

To obviate this, numerous experiments followed, which it is only interesting to the technical student to trace. The revolution has been in the truest sense an evolution. Hundreds of patents have been taken out, and again discarded as useless. Vast sums of money have been expended in the race for superior flour during the last 20 years, and we only now may be said to have settled down on a commonly accepted basis, upon which experts are, broadly speaking, agreed, viz., gradual reduction of the

grain between a series of fluted chilled iron rolls, elaborate purification of the cube-like interior, and then final reduction on smooth rolls, again by gradual degrees, and dressing the results through fine silk cloths.

In olden times, when men had more leisure to linger over the sweets of their occupation, there was a halo of romance about the busy mill close by some lovely brook, but now the competitive condensation of business existence is the prevailing tendency of modern civilisation, and the details of all important industrial and commercial pursuits grow yearly more and more complicated and elaborated, the most ordinary manufactures now involve the application of consummate skill. So that the jolly old miller, who worked and sang from morn till eve, must in some small degree be both a chemist and an engineer, as well as a sound financier, and instead of merrily singing his song of content, he must be eternally puzzling his brains to manipulate a profit for the unpoetic shareholders of some "limited company."

The increasing hurry of a feverish age has long since invaded his quiet mill, once, perhaps, the home of the most tranquil of human occupations.

He can no longer sing, like the typical miller who once lived on the river Dee :—

> "No foresight mars the miller's joy, who's wont to sing and say,
> Let others toil from year to year, I live from day to day,"

as he has now to calculate on the value of crops unsown in some unheard of region at some remote date.

It may be news to many that not only is flour milling an interesting occupation, but it is also the most important industry in the nation from the amount of capital employed. More money by far is invested in this industry than in either that of cotton milling, woollen, lace or silk manufacture.

There are upwards of 3,000 mills in the United Kingdom, giving employment to an immense number of people, scattered about in every town, village and hamlet throughout the country. Many of these, however, have ceased to make flour, owing to the want of capital for introducing modern machinery or want of space or power, but if the English farmer can continue to produce wheat at a profit, numbers of these old mills may hope to resume their busy hum, and the rumble of the water-wheel be long preserved to give charm and romance to many a lovely dell and rippling stream.

Passing now to the mechanical details of the various machines employed, we shall commence with a brief outline of the central machine in the system, which is the roller mill itself, and from the various types of the machine illustrated it will be seen that great differences of opinion have arisen amongst milling engineers as to the most efficient grinding apparatus.

Much of the controversy amongst milling engineers has waged around the design of the roller mill itself, and the growth and development of the modern machine might well occupy a good portion of our time this evening. Amongst the first patents for roller mills was one for rolls made of porcelain. These rolls were placed side by side or horizontally, and the material to be ground was fed in between them from a hopper on the top ; but this type of grinder was not a success altogether, owing to the difficulty of keeping the iron spindle upon which the porcelain roller was to revolve secure in its fastening, and moreover the porcelain surface was liable to wear unevenly, because a differential speed having to be maintained between the two rolls by means of gear, a certain amount of "jar " or vibration was set up which soon showed itself on the grinding surfaces.

The essential features of a successful roller mill were eventually proved to be—firstly—a roll, having elastic levers, which would keep the adjustable roller at its work and at the same time allow any hard or metallic substance which might get between the rolls, to pass through without breaking the lever; secondly, bearings having oil-circulating arrangements ; thirdly, chevron gears to maintain an exact differential speed between the two rollers working together ; fourthly, a reliable adjustment to ensure an even pressure along the whole surface of the roll ; fifthly, a perfectly evenly distributed feed across the roll, which must be spread out in as thin a stream as is possible ; and, lastly, the whole set up in a substantial framework, so as to obviate any tendency to vibration and offering easy access to all parts requiring adjustment, the whole so placed that the machine could be properly ventilated with the dual object of keeping the stock cool and preventing the escape of dust.

I shall now proceed by the help of diagram (I.) to describe the construction and operation of a roller mill with special reference to the adjustments of the rolls. In the first place, I remark that the iron frame is substantially in one casting, and the heavy base provides the necessary solidity. Into the hopper is fed the stock or material to be ground, and according to the supply arriving in the hopper either from the wheat bin in the first stage, or some other source in later stages, there is an automatic spring feed gate L, which hangs down over revolving feed rollers H J the first of which rotates slowly, while the second goes much quicker, so that as the stock proceeds and falls upon the bottom grinding roll E^1, its linear velocity is almost equal to the periphery speed of this roll, which is the slower of the two. The roll E^1 is the slow adjustable one in this case, and is carried on bearings supported on a lever pivotted at F. This pivot is also an eccentric. The opposite end of this lever is the adjusting rod, at the upper extremity of which is a hand wheel C, and at the lower extremity a strong spiral spring in a case D. This adjusting rod is applied at each end of the

roller, so as to admit of separate adjustment at each end, but there is also provided a lever A, by means of which operating on the eccentric B, and an eccentric spindle across the whole length of the roll from one rod C D to the other, both ends of the roll may be adjusted evenly at one motion. Having arrived at the actual grinding surfaces, it will be necessary to remark in passing that these are made of chilled iron cast in an iron mould—samples of which I have the pleasure to exhibit—from which it will be observed that the chill has penetrated the metal some $1\frac{1}{2}$ in. and produced a perfectly even and hardened grinding surface. As these rolls are used in flour manufacture for two purposes, "breaks" and "reductions," to make a difference in the metal used for each purpose is the best practice, and for this reason, that the "break" rolls, after having been ground true on the emery wheel, are fluted or grooved by a special tool with a slight lead or spiral twist of about 1 in. per 1 ft. in the length of the roller, to break open the wheat as it passes, whereas the "reductions" or grindings of the semolina are made on entirely smooth surfaces, so that the metal composing the casting may be more dense and harder. The cast roller is hollow in the middle, but each end is cored so as to require boring to receive the spindle, which is turned slightly larger than the hole left, so that the spindle is forced into its place by means of hydraulic power, and is not keyed on. Experience has shown this to be the only satisfactory method of securing the spindle. Another feature to be pointed out is that the two rollers running in contact are revolving at differential speeds 250 to 100 for "Break" or grooved rolls, and 250 to 200 in the case of the smooth rolls. This differential speed is maintained by means of chevron gears, working in oil-tight cases, so that, when in operation, they are comparatively noiseless.

It will be noticed that the rolls are placed out of the vertical relationship to each other in this diagram, while in diagram (II.) they are almost exactly one over the other, it is the practice of some makers yet to place them side by side or horizontally, as in diagram (III.), but opinion is now generally leaning towards the diagonal method, and for this reason :—The bottom roll is placed so that it acts as an additional feed distributor, and ensures a more even spread of the material to be ground just prior to passing between the point of grinding contact.

Another debatable matter in connection with these rollers is as to which roller of the two should be the fast and which the slow roller. It is obviously mechanically correct to make the fast roll the one running in fixed bearings, and the adjustable roll the slow running one, but in the case of the rolls shown in diagram (I.) this slower roll is placed below the other, so that the pressure is exerted upwards against the top one to do the grinding. Now, this is a matter upon which I should like to hear the opinion of

the members as to which is likely to absorb least power, everything else being eqnal, whether the method shown in diagram (I.) or the one shown in diagram (IV.) where the top roll is the slow and adjustable one, and the bottom roll the fast one, running in fixed bearings, or whether less power would be taken by placing the rolls as shown in diagram (III.) or horizontally. It is argued in favour of the first method that you help to relieve the pressure on the top fast roll bearings by bringing pressure from below, and also get a better feeding device by making the bottom roll take the stock into the grinding contact. It is argued in favour of the second method that the weight of the top roll is utilised to do the grinding, and that therefore much less spring pressure is required, and that therefore this top slow running roller is easier on its bearings; and on behalf of the third method it is stated the pressure on the bearings of each roll is more evenly distributed, and the rolls are more easily kept parallel. Some millers, who have to handle the machines, lean to the idea that the first method is the best for the "Reduction" rollers, and the last method for the "Break" stock.

The second machine of importance is the purifier (fig. 5) which has to deal with all the semolina and middlings made in the process of breaking down the wheat on the fluted rolls. After the little flour has been dusted away this semolina is graded into several sizes, and passes on to the several purifiers, clothed with suitable numbers of woven silk (samples of which are on exhibit) according to the size of the stock with which it has to deal.

This purifier consists of a vibrating sifter D, having a slight inclination from head to tail, and enclosed in an air-tight frame. A fan C is superposed which sucks or draws air up through the silk covered sieve, taking with it all particles of less specific gravity than the pure stock; the latter drops down through the silk into a collecting worm F. The space down the sieve is divided across by wooden partitions, to each of which an air current is applied of varying strength, light at the head end where the silk cover is finest, and heavier at the tail end where the silk cover is coarser.

The air as it passes away from the silk to the fans, ladened with the light impurities, passes through a series of channels E E, placed quite close to the silk, and after passing through these channels expands, and the heavier particles drop into these channels, while the lighter ones pass upwards into a large expansion chamber E C, and are caught while the pure air blows out at the mouth of the fan into the room.

Samples of the purified semolina and the impurities extracted are exhibited. The next operation is that of reducing these purified semolinas and middlings on the smooth rollers already described, and which as far as their mechanism goes are similar

to the fluted rolls which break down the wheat in the initial stage, with the exception that they are provided with scrapers to keep the grinding surfaces clean.

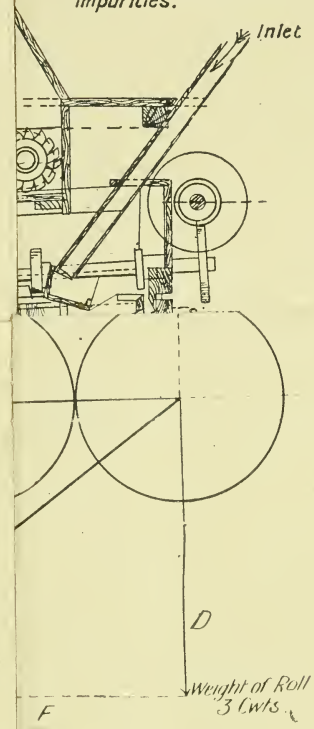
After this grinding comes the dressing or sifting process, which is accomplished on "plansifters" or "centrifugals" The "plansifter" is an attempt to give mechanical action to the old hand sieve, but on mellow English or washed foreign wheat it has not proved such a success in this country as in America or on the Continent, where wheats are ground in a harder condition than here. The "plansifter" is a flat sieve, to which a rotary motion is given by means of a balanced crank, and the sieve is kept clean by means of brushes, operated mechanically or by contact with the inner wall of the sieve.

The "centrifugal," so-called, consists of a circular or polygonal cylinder covered with silk revolving in one direction, while an internal set of beaters revolve in the same direction about ten times as fast, and which beaters have a "lead" or spiral twist of 1 in. to 2 in per foot from head to tail. Into this cylinder the ground meal to be dressed is fed at the head end, by means of a worm attached to the beater shaft, so as to avoid any undue supply of air being admitted. In its passage through this cylinder the meal is so agitated that all the flour is driven through the silk cover until the rejected overtails—too large to go through—pass out at the tail end, and are reground on the smooth rollers until no flour is left worth dressing out, and the final overtails go to offal.

It is a trite saying that "the proof of the pudding is in the eating," and the ultimate test of the miller's work is in the loaf. The engineer who can produce flour of the highest quality from a given sample of wheat is regarded as a genius whose services are in the greatest requisition, and in his efforts he has to pay great regard to the programme of the mill, so that a proper classification of stock shall be effected, and that each machine has a proper relative feed of stock, and that nothing is over-crowded. The flour must all be evenly dressed, and pass through silk mesh of 120 to 160 threads per inch and be free from contamination with the husk of the wheat.

From the infinite varieties of wheat exhibited coming from all quarters of the world, it will be seen that to treat these all successfully great judgment and skill are needed, and the engineer dealing with the problem has to be an expert miller. I have the pleasure of showing you a loaf, baked from flour made on the old stone system, and one baked from the roller or modern system, and I will leave it for the members to judge whether the new system is an improvement on the old or not.

A. Brush cleaning silk
B. Brush cleaning channels in top of silk.
C. Fan.
D. Sieve covered with silk
E. Channels for intercepting impurities.



8 Cwts

DIAGRAM I

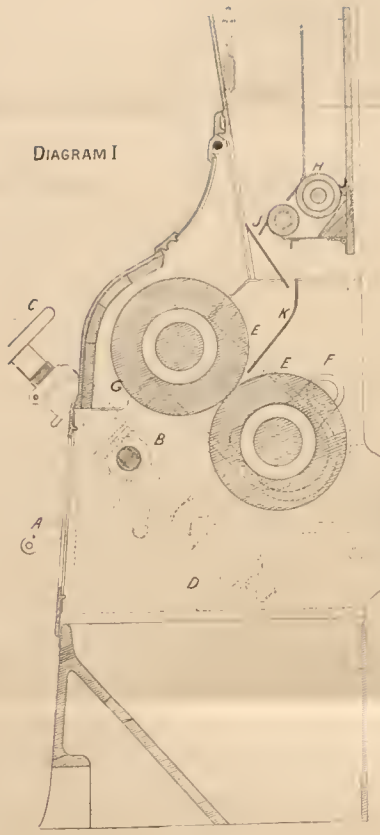
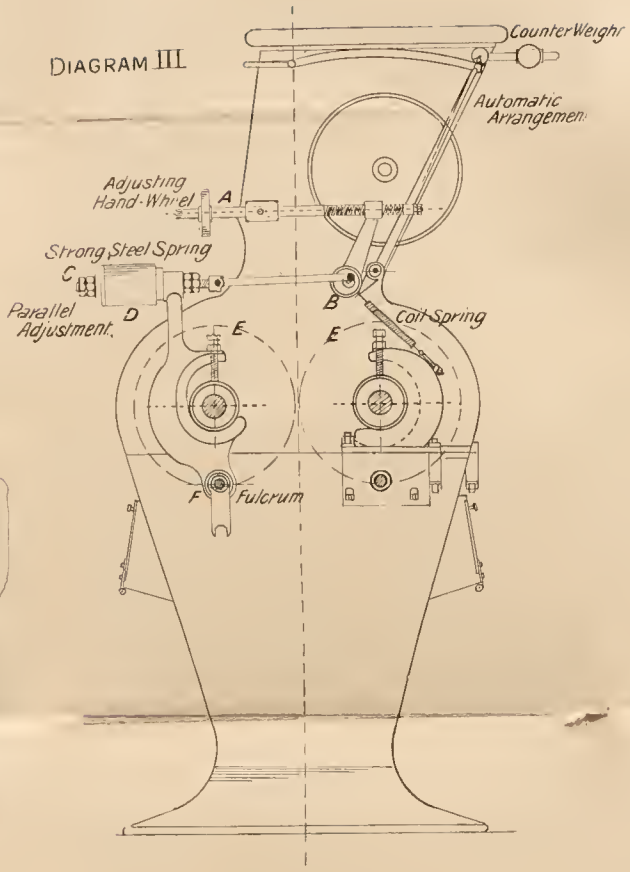
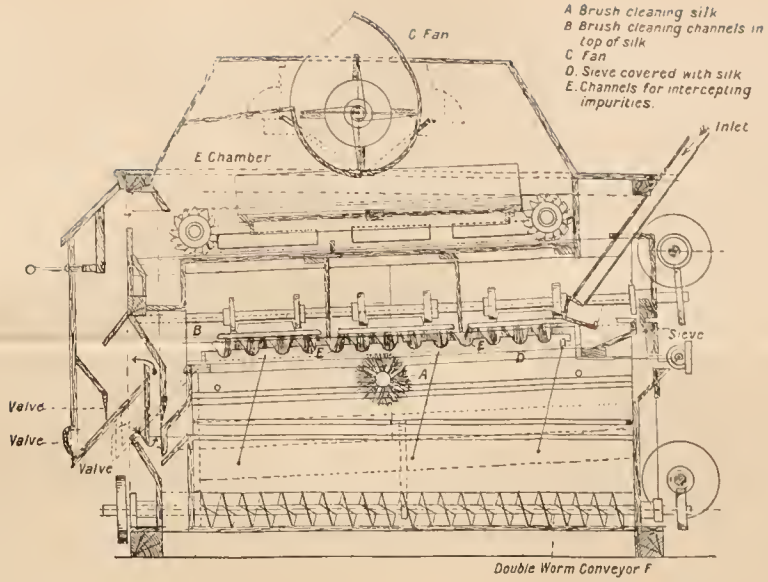
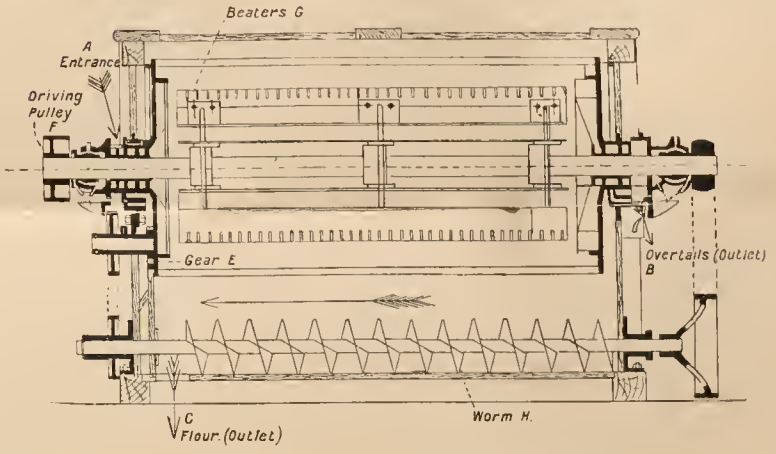


DIAGRAM III







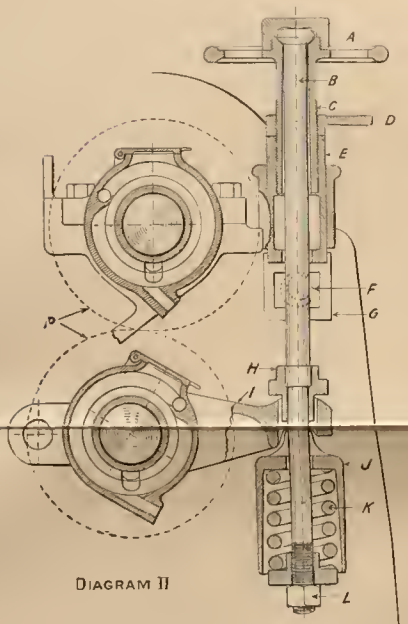


DIAGRAM II

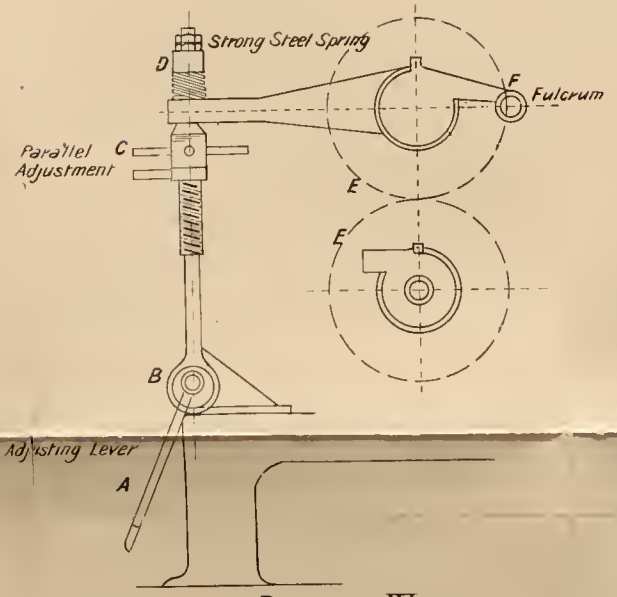
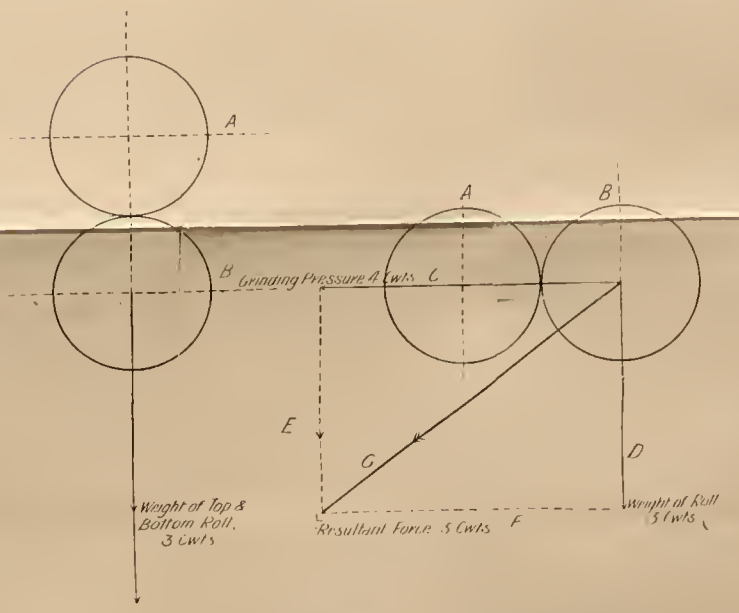


DIAGRAM IV



GRINDING PRESSURE 4 CWTS.
COMPLETE WEIGHT IN BOTTOM BEARING 8 CWTS.

ENGINEERING EXPERT EVIDENCE.

By James F. Reade, A.M.I.C.E.

[Read before Society on Thursday, 2nd March, 1905.]

Every engineer is liable to be called upon to give expert evidence. An engineer may possibly confine himself entirely to the construction of railways, and decline to build—perhaps harbours; but no matter what speciality engages his attention he may be at any time asked to appear in a witness box, and give evidence concerning it.

A moment's thought, and certainly a very short experience in a court of law will convince anyone that it is no easy thing to give evidence satisfactorily. The author has known engineers who, although perfectly familiar with the details of the matter at issue, were nevertheless complete failures as witnesses, succeeding only in confusing counsel and irritating both judge and jury. It is therefore of some importance that engineers should give a measure of attention to the cultivation of those qualities of mind and manner which are required by an expert witness, if he is to discharge his duties as such in the best form possible. There is no school wherein these can be learned thoroughly, except the costly one of experience. Yet what engineer who has ever appeared as a witness will deny that a few hints or a little coaching previously might have made some difference to his feelings after he had given his evidence and had time to reflect.

The author therefore hopes that this Society will think him justified in presenting this paper, containing observations derived principally from his own experience in the capacity suggested by the title.

The characteristics of a good witness are probably inherent, and qualities due to his personality have no doubt been born with him. Yet most men can, by study and concentration of purpose, attain a high degree of excellence in all that is required to fulfil the position with credit. There are exceptions however. Some positively refuse to enter a witness box, because the ordeal causes a nervous reaction which affects them for days afterwards. But generally, determination and experience will enable most people to surmount this; and will also educate them in that true inwardness of the situation which is essential to the best display of even the most brilliant qualities.

Many nice ethical questions can be raised in connection with the moral position of an expert witness. Much the same kind of questions can be put concerning the attitude of solicitors and

counsel. Such discussions have been often started, but as a rule lead to no definite result, and that aspect of the subject is not the one with which this paper is intended to deal. It will suffice if it be agreed to take matters as we find them, and to recognise that in its present imperfect state the world does not seem to be able to get along without the expert and his evidence.

Technical or expert evidence is required in connection with business before certain courts of law—for instance, County Courts, King's Bench and Chancery Courts; also before arbitrations. It is constantly wanted before inquiries held by certain Government departments, such as the Board of Trade, the Local Government Board, &c., and often before Parliamentary Committees and Royal Commissions. The field covered is a large one, and considerable curtailment is necessary to bring it within the limits of a paper. Hence the following observations have special reference to cases in which the witness is subjected to direct and cross examination, as in all legal cases.

When his services are required as a witness the engineer is commonly approached by the solicitor acting for the side in favour of which his evidence is wanted. Sometimes he is employed by the person directly concerned in the case. When he is employed by the solicitor or other agent the engineer should ascertain whether they have full authority from their clients to engage him. The best course is to have his appointment ratified in writing by the principal. The engineer should at the same time make quite clear what his professional charges will be. Otherwise he may find himself presented with a very inadequate sum, and informed that the taxing master has allowed no more.

The scale of allowances to professional witnesses in the taxing office is from one to three guineas per day, nothing being given to cover hotel expenses, assistants' time, &c.

Supposing these things to have been arranged the first real move on the engineer's part will be an interview with the solicitor. An outline of the case is then given to him; he is also supplied with copies of statement of claim and replies thereto. He is shown the opinions of counsel, who may have been consulted; all of these documents must be carefully perused. A general description of what has been done up to that time is furnished; also what attitude the opposite side is expected to assume; what their contentions are likely to be, and what facts they rely upon. What technical evidence is thought to be necessary is mentioned, as well as many other details of more or less importance, which vary in each case. All this should be carefully noted. It sometimes happens that there are certain features in a case with regard to which the solicitor thinks the engineer has no direct concern, and which therefore need not be

communicated to him. This is a mistake. The expert should be told everything, as there can be no rule to determine what concerns him and what does not. He should learn the case in its entirety, which is often no easy thing to do, and usually requires considerable probing. It frequently happens that some apparently remote circumstance furnishes a clue to a line of inquiry which, when followed up, gives valuable results.

It is this matter of being able to seize upon, and combine together the most trivial as well as the most varied points, and forge them into evidence of the kind that will influence a judge and jury, which marks the difference between the valuable and mediocre expert. Should it be necessary to inspect, survey or make other investigations on the premises or property belonging to the opposite party, the engineer should be careful that he is furnished with written permission to do so. Otherwise he may be placed in a very unpleasant predicament.

The investigations to be made depend upon the particular matter at issue, and are very varied in their nature. It will readily be seen that no attempt can be made to even indicate them here for want of the necessary space. It is the possibility of such infinite variety in procedure which gives those opportunities for originality, which, as engineers, we are all supposed to desire. In whatever line of engineering a question may lie, there is no doubt that its investigation for contentious purposes calls for a deep knowledge of the subject and familiarity with its least known aspects.

Full and detailed consideration must be given to every point, whether of a practical or purely theoretical nature. It should never be assumed that any feature, no matter how remote, cannot be questioned. So surely as any such assumption is made, so certainly will the expert be brought face to face with that very point, perhaps at a moment when he is badly prepared to meet it.

Here it may be well to consider the position of an engineer in the capacity of an expert witness, his relation to his employer and to the legal gentlemen engaged in the same interest. Before being retained it is probable that he has had no previous knowledge of the special matter in dispute. Therefore he has been employed to acquire that special knowledge. It is because he is an engineer, and thus possessed of an unique facility for the acquisition of such knowledge that he has been employed. Then he is expected to use his talents, and whatever he may learn during his inquiries, for the benefit of his employer, to help him to defeat some antagonistic interest. Very often his reputation as "a good witness" is the prime cause of his being employed. In other words he has been recognised as one who, from some advantage or peculiarity in manner, diction or other trait, possesses the power of convincing his fellows that his declarations are true and his reasoning correct.

The human mind is so constituted that it presents to different individuals diverse views, and compels them to draw various conclusions from the same set of circumstances. It is seldom that any question which can be reduced to a problem of the two-and-two make four order requires the aid of an expert to settle ; ordinary lay common sense is usually sufficient in such cases. So that the engineer need not be afraid that by taking up his side energetically he must necessarily run the risk of deviating from that strict course which is a *sine qua non* of professional conduct.

It sometimes, however, does happen that the intended witness cannot agree with the view taken by his employer. He must declare this at once, and explain how the difference arises. Possibly some modified course may be possible. But should the disagreement be so great as to be quite irreconcilable it will be his duty to decline to act, and then forget all about the matter. It is not an honourable thing to accept a retainer from the other side, and utilise for its benefit knowledge gained in consultation with the first employer.

On the supposition that he finds it right to act the experts position is peculiar. He is to some extent an advocate, but without the freedom enjoyed by a legal advocate. Counsel is not expected to be impartial ; on the contrary, it is his duty to seize upon and make the most of every point in his client's favour, and minimise everything which may be pleaded against him. An expert is also expected to do something like this, but in a minor and less obvious degree. The best witness is he who disguises this portion of his functions most effectively, and while appearing to be impartial is really making a strong case for his employer or cutting under the foundations upon which the opponent's case stands.

Some witnesses adopt an attitude of indifference, and leave the whole conduct of the case to the lawyers. The expert must do more than this. He should consider himself as one of a group, each having a special function to perform ; he should be at all times alert and ready to co-operate with the other members to attain that success towards which their united efforts are directed. Others again—especially when the case is very technical—seem to think that everything rests with them, even going so far as to quote law to the lawyers, and usually getting snubbed for their pains. Another species will assume a mysterious manner, and cannot be got to impart any definite information, making it difficult for those in charge of the case to be sure of the evidence about to be given. These and other personal peculiarities should be submerged if they have any disorganising influence on that perfect conjunction of forces which should exist between all who are professionally concerned.

When the investigation has proceeded up to a convenient

point, or concluded, as the case may be, it is usual to present a report. In important suits it may be necessary to present more than one, as different stages are reached. Reports should be lucid, and full expositions of the work done and the results obtained. Should any deductions have to be made, the line of reasoning must be clear and easily followed. Combinations of facts used to build up each pertinent conception must be simple and natural. They should also contain impartial descriptions of points favourable to the opponent's contentions, and how these can be best rebutted technically. An opinion may also be given regarding the chances of success of the case, viewed as a whole from a technical standpoint.

The sequence in which the matter of the report is arranged in of importance, because it may be taken as a general rule that the expert will be called upon to give his evidence in chief in the same order as it is placed in his report. The form in which a report may advantageously be submitted to a committee of experts is not necessarily the best in which to place it before a jury of the general public. The witness must consider how his oral evidence will appeal to the jury, and its probable effect on the verdict. Hence the lines on which his report should be drawn up are those that best enable him to explain himself to the court. The order of time and natural sequence of events should invariably be observed. The logical arrangement of deductions and proper emphasis on matter intended to have a desired effect should be carefully considered. Counsel is sure to observe the form of the engineer's report, and his examination will follow it as closely as possible. For various reasons this is so; one being that counsel knows that the witness is already familiar with the subject so arranged.

Should any change in his report be necessary, the engineer will soon have intimation of what is required, either directly from the solicitor or at some of the consultations usually held before the case is heard in court. Modifications are sometimes needed to bring the proposed evidence of several witnesses into line. This does not mean that all the technical evidence must be alike. On the contrary, each witness should be allowed to impress what he has to say with his own individuality. It will be the advocates business to combine the whole in the way he thinks best suited to the requirements of the case. A certain amount of variety in the evidence enables counsel to give more force to his pleading. It is monotonous to hear a number of witnesses say the same thing in the same words. It also produces an impression that it has all been concocted beforehand, which however true in itself had better not be made too obvious to the jury.

It will be the engineer's duty to prepare any maps or drawings to illustrate or explain his evidence. Needless to say that these

should be made in the most clear manner, so that a non-technical person can at once grasp what they are intended to elucidate. To this end every advantage should be taken of distinctive colouring and large bold writing. Distances or dimensions must be clearly marked; notes and explanations must be easily legible, concise, but unmistakable in their meaning. Should the necessity arise the engineer must advise the preparation of photographs, models or maps in relief, &c. But as such things are expensive very good reasons should exist for their use. They must of course be well prepared and neatly finished, and should not be too large, so that they can be easily passed around. The engineer should have full authority to procure such things before he makes himself personally liable for their cost. In court all the above-mentioned objects should be in charge of an assistant, thoroughly familiar with them, and their relation to the various parts of the evidence. It will be better to keep them in the background until wanted; then they should be handed up quickly. Impatience is caused by failure to produce such things immediately they are called for, and what is worse, delay may cause some vital point to be slurred over, so that when counsel has to address the court he may find himself without the evidence he calculated upon to drive home his arguments.

Giving his evidence orally is the real end to which all previous work has been directed. Unless the evidence is fully placed before the court, its proper relation and importance brought out, and its calculated effect realised, it cannot be said that the best result has been obtained. In so far as it falls short of this, the witnesses' object must be regarded as unattained, even though success may favour the side that he is engaged to support. It would of course be unfair to lay all the responsibility for the oral part of his evidence on the expert witness. The examining counsel must take his proper share. A tolerably good witness is often spoiled by an inexperienced examiner, while on the other hand a nervous or unsatisfactory witness can be materially helped by an able advocate. The engineer engaged in a case should therefore take every opportunity, both at consultations and in court. to form some notion of the characteristics and methods of the various counsel retained, that he may have even a slight idea of what must be encountered later on.

There is a great deal of psychological influence set up between counsel and witness; perhaps it is not of quite the same nature in direct as in cross-examination. The advocate has a great advantage. Experience teaches him to perceive quickly the strength and weakness of the individual whom he has to interrogate, and to shape and ply his questions accordingly. The art of advocacy is very ancient, and inumerable writers have expounded its principles. Its rules and methods are very well known to our "learned friends," and form an important item of

their mental equipment. If therefore a witness thinks that it does not very much matter how he gives his evidence he is apt to be mistaken. The chances are that some trained legal mind, versed in the subtleties and foibles of human nature, is on the alert, striking out perhaps an original line of cross-examination which may be found very difficult to combat. Some mannerism or casual observation may embolden counsel to put a question—and what is much more to his purpose obtain a suitable answer—which in other circumstances he might be afraid to ask. When giving evidence an engineer often feels that he is in some way put upon his metal. This is natural enough, and quite unobjectionable if kept within limits. Any high degree of personal feeling is merely playing into the opponents hands, as it may be expected that every weak spot will be noticed and utilised adversely. If a disposition to undue bias can be shown to exist on even one point the fact will be taken advantage of to throw a doubt upon the whole of that witness's testimony.

Calmness, courage and vigilance are essential qualities in an expert witness when giving evidence. He must not be too venturesome in the region of retort or repartee, or in what he may imagine will be accepted as wit. Indulgence in that sort of thing often leads to penitence. Counsel's manner, his aggravating way of putting a question, his sneers or perhaps insolence, his thinly-veiled insinuation, that a long period of penal servitude would be just the thing for you, is no doubt exasperating. Remember however that he is playing his part of the game, deliberately intending to throw the witness off his guard if he can, in order to obtain some advantageous opening. It behoves the engineer to discount such wiles, and keep the real interests of his side of the case ever before his mind.

A good witness will never ask questions. He will avoid such seemingly trivial questions as, Why not? How could that be? &c., and he does not throw his reply into an interrogatory form. The danger lies in the liability to be sharply brought to order, and told to answer, not to ask, questions. Such little questions often give counsel a chance to get in a remark which may cause a laugh at the witness's expense or ruffle his temper. In either case the witness feels that a point has been scored against him; the less he allows himself to be discouraged the better. In answering, a witness has very little scope for practising skilful arrangement, compared with what counsel has in putting questions; the latter can choose his form of interrogation, whereas the former must follow that lead to a great extent.

There are however skilful and unskilful witnesses, as well as examiners, and it sometimes happens that an engineer can, by the substance of his answers, indicate to counsel points which might otherwise be overlooked.

When an opinion or deduction having reference to the special

case in dispute has to be made, it should be supported as completely as possible by facts proved, or to be proved in court. This brings what might be regarded as a supposition more convincingly before the minds of a jury, and, what is also of great importance, it allows the facts to be corroborated by non-technical evidence ; a most valuable help.

The introduction of an apt illustration is a most effective way of explaining what might otherwise remain obscure. No doubt some splendid samples of illustrative simile have been introduced in evidence almost by inspiration ; usually they are much better if carefully prepared beforehand. They must appear to come naturally, for anything that looks like straining after effect in this, as well as in every other part of the evidence, merely weakens it. If an illustration is really apt it will have a good effect with the hearers immediately. On the other hand a jury will instantly detect whatever is unreal ; therefore, unless the witness feels that the simile he proposes to introduce will prove effective, it had better be dismissed. Experience is the only guide that can be trusted in the choice of illustrations which may be employed. The objects to be used in explaining a complication should be such as lie around, and on which the witness can put his hand most naturally—a pencil, sheet of paper, a roll of drawings, &c. It is wonderful what can be done with these simple things when used with discretion, and at the right moment. The author has seen a system of shafting and belting most effectively illustrated with a couple of rulers and a few pieces of tape.

A witness has often much to grieve him when giving his evidence. Some examiners are very clumsy, frequently because they have not made up their case properly. For instance, they may put a series of questions entirely out of the anticipated order, or perhaps quite irrelevant. Then questions are put which should more properly occur in cross-examination, or they are asked so rapidly that the witness does not know which to answer first. Again, there will be an interruption just as an important point is being developed. For all such incidents the expert must be prepared, and not allow them to disturb his equanimity. If interrupted before he has mentioned some necessary matter he should await his opportunity to pick up the severed link, and get in the remainder of his story as unobtrusively as possible. An experienced counsel manages things much more smoothly. He knows when to interrogate, and when to allow witness to proceed in his own way. At the same time the engineer must do his part, and elucidate the points required ; he should never make it necessary for counsel to suggest facts to him, or ask what are known as leading questions ; the evidence should flow freely and naturally, without apparent effort on the part of either examiner or examined.

It should be carefully observed whether the principal and favourable points of the evidence are being noted by the judge. Usually counsel will look out for this, but if witness also sees to it he may in case of necessity be able to effect an improvement by going slower.

The engineer should also watch the evidence of the other technical witnesses co-operating with him, and be ready to suggest to counsel any point to be made clear or which may be in danger of being omitted.

When the professional witnesses on the opposite side are being examined, close attention must be given to what they have to say; it is here that the expert gets his chance to pierce the adversary's armour. To carry out this part of his duty well, requires tact and ability, as well as a minute knowledge of the special features of the case; weak points must be picked out quickly, questions constructed and passed to counsel. There must be no confusion of any kind, and no undue prominence given to the fact that prompting is going on; all must be done with speed, coolness and tact.

In giving his direct evidence a witness often fails from extreme cautiousness or a fear that he may compromise himself or injure his professional reputation; this often arises from an honest desire to say something which shall be incontrovertible. His evidence then becomes a sort of compromise, and the opposing counsel may be relied upon to give him every facility of coming to the ground between the stools of his own indecision. It should be constantly borne in mind that every statement made by one side is open to criticism and contradiction by the other; this must be taken as a matter of course, and a witness should not regard himself too seriously.

When an effective answer or explanation has been given it should not be repeated unless requested. If a good impression is made it is likely to be weakened by reiteration, because of the obvious vanity which inspires repetition; besides, a jury having once grasped a point dislikes having it re-explained; it is merely human nature to look with disfavour on anything reflecting on one's intelligence.

Another fault to be guarded against is a tendency to exaggerate; this is often most damaging when done most unconsciously, and perhaps in the honest belief that the case is being helped. The perspective of facts is often distorted in the witness box. Even a minor note of exaggeration reveals an opening to the opposing counsel, who is usually on the look out for it, as he well knows that an unbiassed witness is exceptional. Should the exaggeration be made obvious to the jury it often results in their discrediting all that particular evidence in a greater degree than it deserves. Nevertheless, evidence should be given in no uncertain tone. The average mind has very little trust in its own reasoning

powers, and positive assertion from an authoritative source often passes unchallenged. In the witness box, however, the advantage which could be taken of this trait in humanity, can be used only in a very modified way ; the judge and legal gentlemen opposed being usually proof against evidence of that sort, will discount it, aud form their opinions on the matter of the statement itself. A distinct enunciation, an easy delivery, and the most pleasant and good-tempered manner possible must be cultivated, as well as any other arts calculated to give effectiveness to the statements. Volubility is an evil, and must be guarded against ; on the other hand, taciturnity is likely to produce an unfavourable impression by making the witness appear as if he had something to hide.

The final test of the engineer's fortitude will be the cross-examination. If he breaks down under this all previous work has been in vain ; it is the most dangerous ordeal he has to go through. In no portion of his duties are the best qualities required so much as in this ; for in addition to his own personal difficulties he has the responsibilities of the case in a great measure resting on him ; no warning can be given him when he is nearing dangerous ground ; he must stand alone with the enemy.

The process of cross-examination may be regarded as a mental contest between witness and counsel, in which the latter holds advantages of one kind, and the former is in a position to be assailed.

The witness's main preparation must be derived from a study of the case for the opposition. He should analyse his own evidence, and consider how each part may be attacked and how it may be best defended. In a somewhat similar manner as he first devised how the case as a whole should be set up, so he must now find out how it could be weakened or destroyed.

He must be ready with his defence simultaneously at all points, because he can expect nothing like the natural sequence of facts now. Indeed it is a very usual thing with some cross-examiners to ask a series of questions in fairly rapid succession, several of which are purposely placed out of their natural order, and many of little or no importance, so that a witness may be betrayed into giving inconsiderate answers.

The worst possible attitude for the expert to assume is when he allows himself to give pettily clever or obtuse answers ; these produce either laughter or irritation, and in either case such a witness may reflect at his leisure that the case has been lost so far as his efforts have been concerned.

It is very damaging to the opponents case when his counsel elicits an answer in cross-examination directly contrary to his interests. An expert must be always on the look out for openings, where he can judiciously drop in replies injurious to the cross-examiners purpose. A few such replies have a very discouraging effect on counsel, and an engineer may consider

himself to have achieved something if he finds that he is dismissed before his cross-examination has been thoroughly completed. But the feelings are not to be envied of that expert who, like a man in a punt, feels the pole—or his arguments—stuck firmly in the mud, and his frail boat—or the only few facts he possessed—gently but surely gliding away on the stream of cross-examination.

Very much more could be written on this subject, but space will not allow. It involves a study of human nature, and must therefore be always interesting, but beyond this it has a professional aspect which is important.

Let no man think that perfection can be attained, for what may appear good in one individual may be entirely out of place in another. There are always new pitfalls and new entanglements amongst which the most experienced may make mistakes; so there must also be new ways of getting out of difficulties. Hence it may be said that the greatest expert witness, like the greatest general, is: "he who makes the fewest blunders."

DESIGN OF CONCRETE-STEEL BEAMS.

By W. Noble Twelvetrees, M.I.Mech.E.

[Read before the Society on Thursday, April 6th, 1905].

Concrete has long been recognised as one of the most valuable materials of construction, and as one which has been used for many centuries in works where strength and durability were most essential.

So far as steel is concerned there is every assurance as to strength, its only weak point being that of susceptibility to climatic influences. As the physical strength of steel is valuable for supplementing that of concrete in which it may be embedded, so what may be called the "constitutional" strength of concrete is valuable in preserving steel from corrosion.

In steel and concrete, then, we have two materials, of which the most prominent features are respectively strength and durability. The problem is to effect their combination in such manner that they may be employed to satisfy the requirements of scientific construction. The solution is to be looked for in the union of concrete and steel in such a way as to produce what is practically a new material, possessing the solidity that characterises masonry construction, while ensuring ample stability, strength and stiffness. Compliance with these conditions is rendered possible by combining the materials so as to form what is described by the generic term "concrete-steel," or reinforced concrete.

It is well known that the use of concrete alone is limited to classes of work where high compressive strength is one of the chief requirements, as the low tenacity of concrete makes it, like cast iron, an extremely uneconomical material of construction for many purposes.

Taking, as an example, the case of a concrete beam supported at the ends and loaded in the centre, we find the upper or compression side is capable of supporting at least ten times the load that would cause failure of the lower or tension side. This undesirable inequality of resistance can be adjusted by embedding steel so as to take the tension encountered in the lower portion of the beam, thus permitting the strength of the upper part to be fully utilised in supporting much greater loads than would otherwise be possible.

Adhesion of Concrete to Steel.—Adhesion of the concrete to the steel is a matter of prime importance, and without it the distinctive

qualities of concrete-steel could not be realised. The high resistance of the combination is largely due to the fact that the constituent parts adhere so strongly one to the other that the action is that of a homogeneous structure. Adhesion enables the concrete to offer resistance against sliding along the surface of the steel, and thereby facilitates the transference of forces from one material to the other. The result is uniform behaviour somewhat akin to that obtained by the employment of iron or steel plates in the ordinary flitch-beam.

Various experiments have been carried out with the object of determining the adhesion of concrete to steel.

Dr. Ritter states the value to be from 568 lb. to 668 lb. per sq. in., and similar values are given by Professor Bauschinger.

The general practice of engineers on the Continent and in the United States is to adopt 570 lb. per sq. in. as the basis of calculation, but this is too high a value for plain rods or bars.

Function of the Reinforcement.—The primary function of the steel used as reinforcement is to resist tensile stress. It has also to resist shearing stress, and sometimes compressive stress. But an important function of the reinforcement is to insure the thorough distribution of strain in every part of the concrete in which it is embedded, thus preventing the concentration of strain and consequent rupture at any point where there may be an element of weakness. In the case of a beam, the steel has chiefly to resist tensile stress, and if it be applied in large units—such as bars of T or I section—it will be impossible to attain the required result. Here we find the line of demarcation between ordinary "steel and concrete" construction, and concrete-steel construction. In the former, the steel beams and joists constitute the main source of strength, supporting the applied load and the weight of the concrete, receiving little or no aid from the concrete, and imparting no new qualities to that material. In the latter, the steel reinforcement is not expected to do more than half the work, as the concrete takes care of compressive stress. Further, it is known that the concrete actually resists part of the tensile stress, thus reducing still further the duty of the steel. At the same time, the steel increases the original resistance and elasticity of the concrete.

Methods of Calculation.—Although it is the fact that concrete acquires greatly increased strength when combined with steel, a very usual practice is to allow nothing for the value of the concrete in the tension area of a beam, so far as concerns resistance to flexure.

In the case of a steel beam, where resistance to tension and compression is of equal value, the neutral axis must pass through the centre of gravity of the section. This is not so in a beam of simple concrete, for the position of the neutral axis is affected by the fact that the compressive strength of the material is greater

than its tensile strength, and as stress increases, the neutral axis moves away from the axis through the centre of gravity of the section.

Therefore it is necessary to inquire what is the probable position of the neutral axis in a beam where compressive stress is not limited by the low tensile resistance of the material.

Taking 10 : 1 as the ratio representing the compressive and tensile strength of concrete, it can be demonstrated by mathematics that the proportionate depths of the compression and tension areas in a rectangular beam of simple concrete will be about one-fourth and three-fourths of the depth of the beam, respectively.

By adding steel in the tension area to such an extent as to make the resistance of steel + concrete ten times greater than the resistance of concrete in the compression area, we should get the converse of the previous condition.

In one case the neutral axis would be near the top of the beam, and in the other near the bottom. Between these extremes any required variation may be effected by adjusting the relative resistance of the materials in the compression and tension areas. Thus the position of the neutral axis in a concrete-steel beam depends upon the proportions of concrete and steel, and upon the disposition of the steel with respect to the neutral axis.

From the foregoing it is clear that the height of the neutral axis may be calculated for any beam after these details have been settled, or that the proportions of concrete and steel may be adapted to any chosen position for the neutral axis.

The ordinary rule $f = \frac{3}{4} Wl \div bd^2$, for determining the stress in solid rectangular beams under uniformly distributed load does not differentiate between stress at the upper and lower fibres, and it follows that the results thereby obtained can only apply to the case of beams in which the neutral axis passes through the centre of gravity of the section.

When dealing with beams of concrete-steel, where in addition to the effects of differences in the resistance of concrete to tension and compression we have to consider the effects due to the quantity and disposition of the steel, the formula is absolutely useless and some alternative method of calculation becomes necessary.

Formulæ derived from Beam Equations.—The following simple rules have been derived, from equations in ordinary use, for the purpose of making clear the general principles adopted in the design of concrete-steel beams. These rules are deficient in the respect that the relative values of the coefficients of elasticity of steel and concrete are not introduced as factors, but this omission does not materially affect the accuracy of the calculated results.

The bending moment (M) developed in any beam must always be resisted and held in equilibrium by the moment of resistance (R)

of the section. Therefore, in every case the bending moment must be equal to the moment of resistance; or $M=R$.

For a uniformly distributed load on a beam, of the length l, supported at each end, $M=Wl\div 8$, and the general expression for the moment of resistance is $R=f\,I\div h$. As $I=bd^3\div 12$ for a rectangular beam, and $d=(h+h)$, we get

$$R=fbh\tfrac{2}{3}h$$

where f = extreme fibre stress, at the distance h from the neutral axis; b = breadth of the beam section; and h = distance of the extreme fibres from the neutral axis.

Equating the expressions for M and R we have

$$\frac{Wl}{8}\times\frac{1}{fbh\frac{2}{3}h}=1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Whence

$$f=\frac{Wl}{5\cdot\dot{3}bh^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and

$$W=\frac{5\cdot\dot{3}fbh^2}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Formula (2) gives the extreme fibre stress at the top or bottom of a rectangular beam, but in the case of a steel bar used as reinforcement in the tension area, the resistance of the concrete is usually neglected, and the stress is regarded as being concentrated at the centre of the bar. By eliminating the quantity bh from formulæ (2) and (3), and using F = total force instead of f = intensity of extreme fibre stress, we should get

$$F=\frac{Wl}{5\cdot\dot{3}h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and for the load

$$W=\frac{5\cdot\dot{3}\,Fh}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

But as the intensity of stress in a beam diminishes progressively from the extreme fibres towards the neutral axis, where its value = 0, the mean unit stress is $(f+0)\div 2=\frac{1}{2}f$. Hence formula (4) gives double the correct value for the total stress F, and formula (5) gives half the correct value for the corresponding load W. Therefore the equations must be modified as below.

Denoting total tensile stress, considered to be concentrated at the centre of the reinforcement, by the symbol F''_t, and the distance from the neutral axis to the bottom surface by the symbol h_y, we have

$$F''_t=\frac{Wl}{\frac{1}{2}5\cdot\dot{3}h_y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and for the load

$$W=\frac{5\cdot\dot{3}F''_t h_y}{l}\times 2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

If reinforcement be used in the compression area of a beam the total stress on the steel can be determined by the rule

$$F''_c = \tfrac{1}{2}\frac{(W - W')l}{5 \cdot 3 h_x} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where F''_c = total compressive stress on the steel, W' = calculated proportion of load carried by the concrete, and h_x = height of the compression area.

It is often the case that the centre of the reinforcement is not placed at the same distance from the neutral axis of the section as the theoretical centre of pressure of the tension stress area. For use under such circumstances, formula (6) must be modified by substituting the value of the actual distance between the centre of the reinforcement and the neutral axis.

Thus $$F''_t = \tfrac{1}{2}\frac{Wl}{8(h_y - z)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Here z is the distance between the centre of the reinforcement and the bottom of the beam.

Total stress on the reinforcement in the compression area at any distance from the neutral axis other than $\frac{2}{3}h_x$, must be calculated by a modification of formula (8). Thus

$$F''_c = \tfrac{1}{2}\frac{(W - W')l}{8(h_x - x)} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where x is the distance between the centre of the reinforcement and the top of the beam.

When the height of the compression area (without reinforcement) is known, the width of concrete section can be found for any load and span by an equation derived from formula (1).

Thus, denoting compressive fibre stress in the concrete by f'_c, and the distance from the neutral axis to the top surface by h_x, we have

$$b = \frac{Wl}{5 \cdot 3 f'_c h_x^2} \cdot \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The foregoing rules assume the depth, load and span of the beam to be definitely fixed, and the height of the neutral axis to be known. In such cases they can be used to find the required areas of steel and concrete to comply with the stated conditions. But it is easy to derive equations equally available for determining the proportions of a beam to suit any load and span if the essential factors are known.

For instance, to calculate the height of the compression area from the load, span, and width of the section, and the unit stress of the concrete, we get from formula (1).

$$h_x^2=\frac{Wl}{5\cdot\dot{3}\,bf'_c},\text{ or }h_x=\sqrt{\frac{Wl}{5\cdot\dot{3}\,bf'_c}}\quad\ldots\ldots\quad(12$$

If the compression area is to be square in section we have

$$b^3=bh^2=\frac{Wl}{5\cdot\dot{3}f'_c}$$

$$\text{or }b=h=\sqrt[3]{\frac{Wl}{5\cdot\dot{3}f'_c}}\quad\ldots\ldots\quad(13)$$

In the tension area, the required distance of the reinforcement from the neutral axis will depend upon the area of steel used; and, conversely, the area of steel will be governed by its distance from the neutral axis.

Denoting this distance by the symbol h_v, we can determine the required value for any case by a modification of formula (9), adding the factor a = area of steel.

Thus
$$h_v=\tfrac{1}{2}\frac{Wl}{8f''_t a}\quad\ldots\ldots\quad(14)$$

Where f''_t = permissible stress per sq. in. on steel in tension and a = area of steel in square inches.

To prove the accuracy of calculations made by the above formulæ, the resistance of each area may be calculated by a formula derived from the expression for the moment of resistance.

Thus
$$R=F''_t(h_y-z)+(f'_m bh_x\tfrac{2}{3}h_x).\quad\ldots\ldots\quad(15)$$

The first term of this formula gives the resistance of the steel in tension, and the second the resistance of the concrete in compression. Here f'_m = mean stress per sq. in. on the concrete.

Table I gives the width of concrete and area of steel as calculated by formulæ (3) (6) (8) (9) (10) and (11) for concrete-steel beams 12 in. deep with a clear span of 100 in., and under a uniformly distributed load of 4,000 lb. The heights of the neutral axis and the steel axis were assumed, and the permissible fibre stresses were taken as follows :—

Steel, in tension and compression...15,000 lb. per sq. in.
Concrete in compression* ... ... 500 ,, ,, ,,
,, ,, tension* ... ... 50 ,, ,, ,

The cross sections of the beams are represented in Figs. 1 to 4.

* For proportions of concrete see Appendix II, p. 79.

Table I.—Calculated Proportions of Concrete-Steel Beams.

(Uniformly Distributed Load 4,000 lb. Span, 100 inches.)

Fig. No.	Dimensions of Cross Section of Beam.		Height of Neutral Axis above Bottom of Beam.	Height of Steel Axis above Bottom of Beam.	Area of Steel. No Allowance made for Tension in Concrete.	Area of Steel, allowing for Tension in Concrete.
	b	*d*				
	In.	In.	In.	In.	Sq. in.	Sq. in.
1	6	12	7	2·33	0·35	—
1	6	12	7	2·33	—	0·28
2	6	12	7	2·	0·33	—
2	6	12	7	2·	—	0·268
3	9·37* / 4·33	12	8	2·	0·27	—
3	9·37* / 4·33	12	8	2·	—	0·226
4	6	12	8	2·	0·27	0·206 / 0·30*

* Compression Area.

Table II. gives the height and width of the compression area, and the height of the tension area as calculated by formulæ (12) (13) and (14) for different areas of steel for concrete-steel beams with a clear span of 100 in., and under a uniformly distributed load of 4,000 lb. The permissible fibre stresses have been taken at the same values as for Table I.

Table II.—Calculated Proportions of Concrete-Steel Beams.

(Uniformly Distributed Load 4,000 lb. Span of 100 inches.)

Compression Area.		Tension Area, height for Areas of Steel stated below.				Dimensions of Beam ($b \times d$) for Areas of Steel stated below.							
						1 sq. in.		¾ sq. in.		½ sq. in.		⅓ sq. in.	
Width.	Height.	1 sq. in.	¾ sq. in.	½ sq. in.	⅓ sq. in.	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
10·	3·87	3·66	4·22	5·33	7·0	10·	7·53	10·	8·09	10·	9·20	10·	10 87
6·	5·					6·	8·66	6·	9·22	6·	10·33	6·	12·00
5·3	5·31					5·31	8·97	5·31	9·53	5·31	10·64	5·31	12·31

Fig. 5 shows various cross sections of beams based on the dimensions stated in columns 7 to 14 of Table II.

It will be understood that the width of the tension area need not necessarily be the full width of the compression area, the chief point for consideration being the provision of ample width

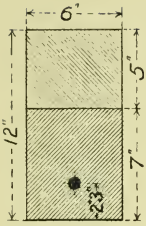


FIG. 1.

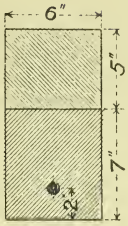


FIG. 2.

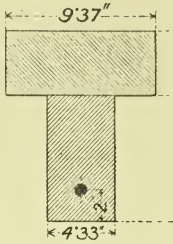


FIG. 3.

FIG. 4.

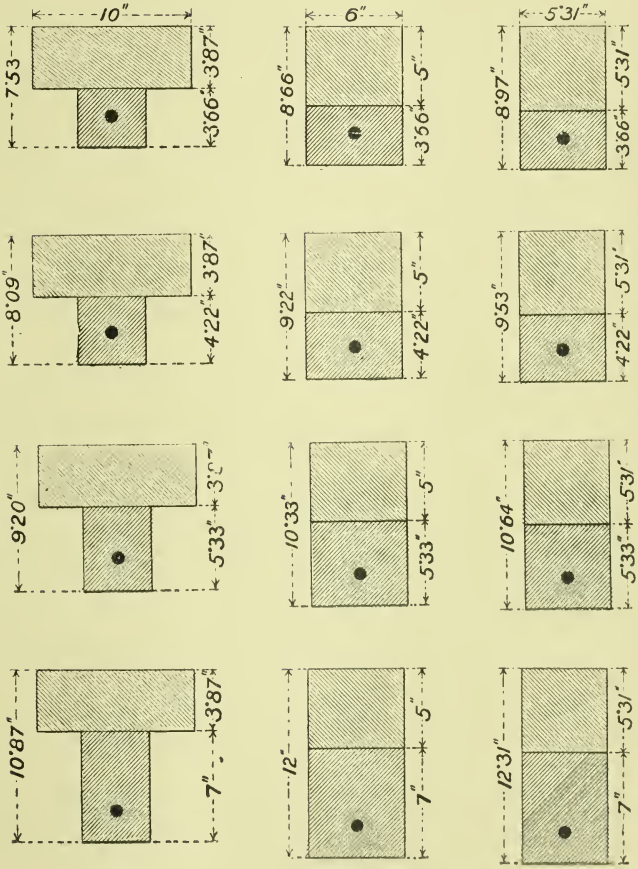


FIG. 5

for the proper spacing of the steel bars. In many cases, however, no practical advantage would be gained by making the width of the tension area less than that of the compression area, as the additional cost of moulds would more than counterbalance any saving due to reduction in the quantity of concrete.

Shearing Stresses.—The formulæ hitherto discussed are based on the assumption that if sufficient steel be employed for resisting bending moments, shearing stress may safely be left to the concrete. No doubt the concrete is perfectly capable of taking shearing stress up to a certain limit, within which the safety of the beam may be fully assured, but greater strength is attainable by more complete conformity with theoretical requirements.

In this connexion it may be mentioned that, in various experiments made upon concrete-steel beams, fracture has resulted without any evidence being given of slipping of the concrete on the steel. Still, in short and heavily-loaded beams, and in long beams where a high percentage of reinforcement permits heavy loading with a relatively small sectional area of concrete, the shear may become excessive, and in such cases it is important to ascertain whether the intensity of horizontal shear is likely to overcome the adhesion of the materials.

As the state of simple shear is one in which there are two principal stresses only, giving rise to a stress that is wholly tangential on any two planes inclined at 45 deg. to the axes of principal stress, and that is equal in intensity to the intensity of either of the principal stresses, it is evident that the reinforcement used for resisting shearing stresses should be perpendicular to the planes subject to normal stress. Further, as shearing stress in a beam, under a uniformly distributed load attains its maximum value at the supports and decreases in value towards the centre, the dimensions of the reinforcement may be diminished progressively towards the centre, or alternatively, the spacing of the bars may be increased. The tension on diagonal planes in a beam can be calculated in a manner similar to that adopted in connection with the design of braced steel girders, and need not be discussed in detail.

Floor Design.—A concrete-steel floor system can readily be evolved from a collection of simple beam forms.

In the first place, let us consider a beam in which the reinforcement in tension is such that, for the proper balancing of resistance, the concrete in compression must be extended in the form of a wide flange, giving a T-shape to the cross-section of the beam.

A little consideration will show that a very wide upper flange, whether of concrete alone, or of concrete with longitudinal rods, would be weak laterally, and might tend to crack or to break off from the main body of the beam. Hence, transverse reinforcement could be added with advantage.

The resulting beam would consequently be of T-section with longitudinal reinforcement near the bottom and a network of rods placed longitudinally and transversely, near the top.

It is evident, then, that the general proportions of the beam and the width of the compression flange can be varied at pleasure for a given load by corresponding adjustment of the reinforcement. The latitude so given is of considerable value in the design of flooring systems.

Let us take one floor panel, in which the main girders are 8-ft. apart, and the transverse girders, or joists, are 4-ft. apart.

We assume that, by suitable adjustment of the reinforcement, the compression flanges of the main girders have been made 4 ft. wide and say, 4 in. thick. Then, between the centres of two consecutive girders, spaced 8 ft. apart, there will be an interval of only 4 ft., as each of the compression flanges projects 2 ft.

Similarly, it is assumed that the top flanges of the joists are made 2 ft. wide. Consequently the interval between successive joists will only be 2 ft., as the compression flanges of the joists account for the other 2 ft. of the distance.

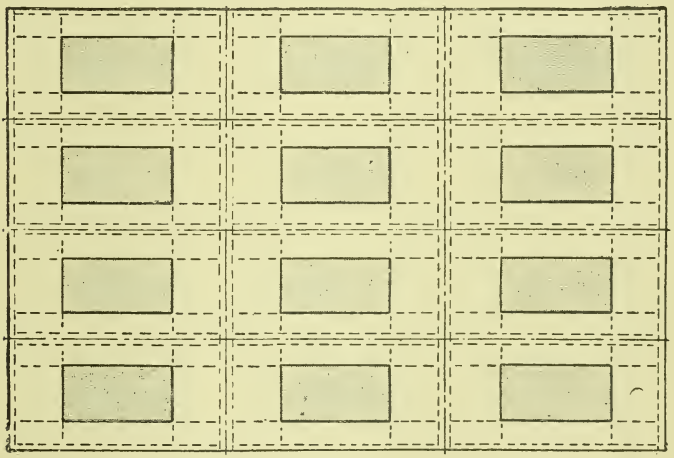


Fig. 6.

As shown in Fig. 6, the general result is that the assumed floor panel is complete, with the exception of a series of rectangular spaces, such as those represented by the shaded areas in the diagram, each space measuring 4 ft. by 2 ft. These spaces can be filled in with concrete 4 in. thick, and the floor is thereby finished.

It will be understood that in practice the spaces would be closed concurrently with the formation of the top flanges of the

girders and joists. Practically, therefore, the whole of the floor slab forms the compression flange of the connected system of beams.

Further, assuming the top flanges to be reinforced by longitudinal and transverse rods, it is a natural step to conclude that all these rods should be laid continuously from end to end of the span, and from side to side in the width of each panel.

The additional cost of the metal would be quite inconsiderable and the cost of labour would propably be reduced because the rods would not have to be cut, and the number of separate pieces would be smaller. These rods would then occur at predetermined intervals in the flanges of the girders and joists, and would also continue across the concrete filling the parts of the floor system not covered by the previously defined widths of the flanges.

Here we have an additional feature of strength due to the reinforcement of the whole of the floor slab by steel rods running in two directions, and thus binding the construction still more firmly together.

It will also be seen that in a floor designed in the manner here outlined, each of the joists acts as a stiffener for the flanges of the adjoining girders, and that the entire structure is so interconnected that an exact calculation of its strength is practically impossible.

But we have a further element of strength, arising from the action of the various spans after the manner of continuous beams.

Again, interior arching effect, due to the action of adjoining floor panels, adds about one-third to the area of the compressive stress diagram, the additional compression being taken up by adjoining floor panels, instead of by the reinforcement.

Something may also be allowed for the arching effect produced by a uniformly distributed load. It must be borne in mind, however, that no allowance for arching effect should be made in the case of loads that are liable to "flow" like corn and other loose materials.

The arching action necessarily varies with the deflection and with the details of design, but the result of practical experience is to show that the increased resistance thereby given to a span of 4 ft. may be generally stated at 50 per cent.

Fig. 7 is a diagram prepared by Mr. A. L, Johnson, and reproduced from the Proceeding of the American Society of Civil Engineers*. From this the percentage for a span of any length up to 25 ft. can be read off.

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* Proc. Am. Soc. C.E. Vol. XXVII., No. 6.

We now have the following simple method of determining the proportions of beams used in floor construction:

1. Calculate the values of the moments of resistance by the rule previously stated for simple beams.

2. Double the values so obtained, to allow for continuous girder action and the arching action of adjoining floor panels.

Add a percentage from Fig. 7 corresponding with the length of span, to allow for arching effect caused by a uniformly distributed load.

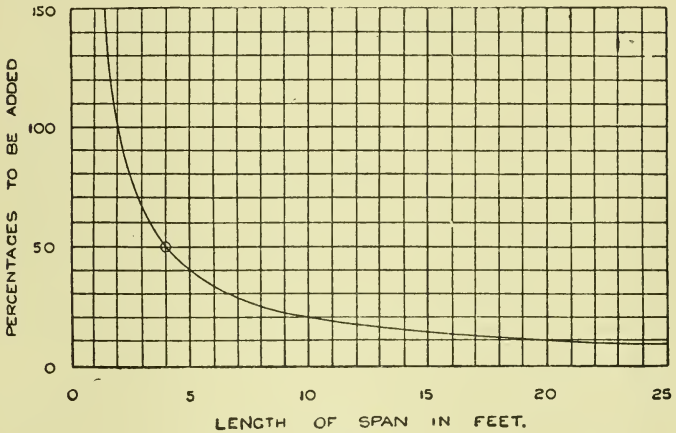


FIG. 7.

Typical Forms of Beam Design.—Detailed discussion of the principal types of the almost endless variations that could be made in the design of concrete-steel beams is scarcely necessary. It will be useful, however, to add a few notes relative to different primary forms of design suitable for general adoption.

The simplest possible form for a supported concrete-steel beam is one having horizontal reinforcement consisting of one or more bars placed near the bottom of the beam, for resisting tensile stress. Compressive and shearing stresses are taken by the concrete without assistance.

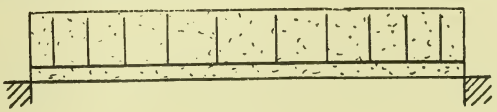


FIG. 8.

In Fig. 8 a similar beam is represented, but shearing stress is here resisted wholly or in part by vertical ties or stirrups. The auxiliary reinforcement can be formed of round rods, or of flat strips of steel, as may be preferred.

FIG. 9.

In Fig. 9 the main reinforcement is the same as before, but the auxiliary reinforcement is placed diagonally, for reasons that have been discussed above.

FIG. 10.

In Fig. 10 we have a suggested method of applying expanded metal for taking stresses arising from shear. The metal can be applied in the form of separate sheets, the lower edges wrapped round the outer rod of the reinforcement on each side of the beam ; or in the form of a trough, the bottom of which would lie under the longitudinal reinforcing rods. In the latter arrangement a considerable part of the tension due to bending moment would be carried by the expanded metal. The main reinforcement is disposed similarly to that in previous examples.

In large beams, where the amount of metal might form a considerable item of expenditure, the proper course for adoption would be to employ two or more troughs of varying length, and fitted one inside the other, so as to give the required graduation of resisting power, somewhat after the manner in which engineers graduate the plates of a built-up girder.

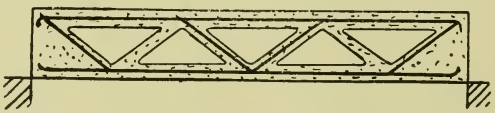


FIG. 11.

In Fig. 11 the beam is designed on the principle of the "Warren" girder. Both the top and the bottom flanges are reinforced, the latter with more metal than the former; the diagonal web members in tension are reinforced; but the diagonals in compression rely upon the concrete for the necessary resistance. This beam is a framed structure, consisting of clearly defined flanges and diagonals as shown in the drawing.

FIG. 12.

In Fig. 12 is shown another type of framed beam designed on the principle of the Linville truss, and it should be noted that the spacing of the tension members of the web is one half that of similar members in the " Warren " type.

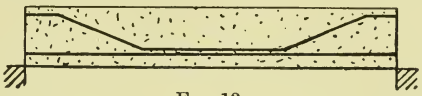


Fig. 13.

In Fig. 13 we have longitudinal horizontal reinforcement, consisting of one or more bars near the bottom of the beam, and additional reinforcement consisting of one or more bars bent in an upward direction near the supports. The horizontal part of the latter reinforcement is shown above the first-mentioned bars for the sake of clearness, but in practice it is usually situated in the same horizontal plane. The concrete, acting in conjunction with the steel bars, practically forms a trapezoidal, or queen-post, truss. This type of construction is most suitable for beams with fixed ends, and for continuous beams.

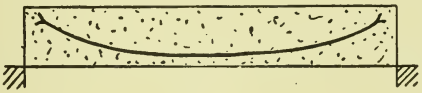


Fig. 14.

In Fig. 14 we approach another method of reinforcing concrete beams, in which the reinforcement is shown bent into a curve similar to that forming one boundary of the bending moment diagram of a supported beam under a uniformly distributed load. Although theoretically correct, so far as bending moment is concerned, this arrangement does not lend itself conveniently to the application of ties for resisting shearing stress, and in practice it will be found to involve more expense and trouble than the use of other forms of reinforcement.

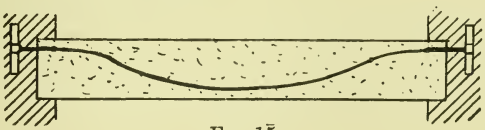


Fig. 15.

In Fig. 15 the last mentioned system is shown in connection with a beam having its ends firmly fixed in the walls of a building.

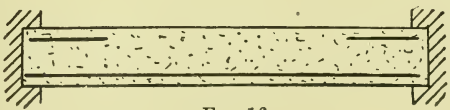


Fig. 16.

In Fig. 16 is shown another system of reinforcement, providing in a very simple manner for the incidence of tensile stress in a beam fixed at the ends, and although this mode of treatment does not conform so closely with theoretical requirements as the method described above, it can be applied easily and cheaply.

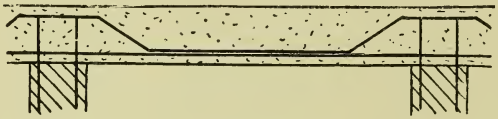


Fig. 17.

In Fig. 17 we have part of a continuous beam, where the conditions generally resemble those in a beam with fixed ends, and in this diagram vertical reinforcement is shown in the supports, connected to the bent ends of the bars, serving to resist tension up to the points of contrary flexure and afterwards in the central portion of the beam.

A further modification of design is suggested by the application of the tubular system to beam construction. In this way the usefulness of a specified quantity of concrete can be increased, or for a specified duty the quantity of concrete can be reduced.

The area of concrete removed, below the neutral axis, would have been of comparatively little value for resisting tension, and if, as usual, the tensile strength of concrete is not taken into account, the theoretical loss is nothing.

The foregoing examples are sufficient to suggest the principal features embodied in concrete-steel beams, and, as each type illustrated is susceptible of further modification and development, it will be seen that an almost infinite variety of design is available for the structural engineer.

APPENDIX I.

Comparison of Results Calculated by the Foregoing Formulæ with Experimental Results for Concrete Beams.

For the purpose of this comparison results have been selected from a series of experiments conducted by Professor W. Kendrick Hatt, of Purdue University, U.S.A. The tests were conducted on concrete-steel beams, measuring 8 in. square, and the clear span between supports was 80 in. The reinforcement consisted of ordinary round iron bars, and failure was considered to have taken place when a point was reached, after which deflection began to increase rapidly without any corresponding increase of the load. This point corresponded approximately with the elastic limit of the iron, and did not represent the ultimate strength of the concrete in compression.

The results are given in the subjoined table, where also will be found the theoretical load, compressive stress in concrete, and height of neutral axis as computed by Professor Hatt.

Table (a)—Calculated and Observed Results (Professor Hatt).

Cross Section, 8 in. square; Clear Span, 80 in.; Elastic limit of Reinforcement, 36,000 lb. per sq. in.

No.	Reinforcement.		Load at Failure (Central).	Calculated Load (Central).	Calculated Stress in Concrete Compression.	Calculated Height of Neutral Axis.
	Percentage.	Height from Bottom.				
		In.	lb.	lb.	lb.	In.
(1)	1	2	5,500	5,470	1,699	5.82
(2)	1	1	7,300	6,705	1,810	5.61
(3)	2	2	10 250	10,840	3,050	5.30
(4)	2	1	12,000	12,515	2,710	4.94

In the calculations which follow, the author has employed modified forms of formulæ (12) and (9) to suit the expressed condition of central loading.

The compressive stress in the concrete, as calculated by Professor Hatt, has been taken as the basis for calculating the height of the neutral axis, and the other data are those stated above.

No. I (*a*)—The distance of the neutral axis from the top of the beam is determined by formula (12) modified thus :

$$h_x = \sqrt{\frac{Wl}{2.6bf'_c}} = \sqrt{\frac{5{,}500 \times 80}{2.6 \times 8 \times 1{,}699}} = 3.48 \text{ in.}$$

(*b*)—Total tensile stress in the reinforcement is calculated by a modification of formula (9) :

$$F''_t = \tfrac{1}{2}\frac{Wl}{4(h_y - z)} = \tfrac{1}{2}\frac{5{,}500 \times 80}{4(4{\cdot}52 - 2)} = 21{,}825 \text{ lb.}$$

(*c*)—The area of steel required is :

$$a = F''_t \div f''_t = 21{,}825 \div 36{,}000 = 0{\cdot}606 \text{ sq. in.}$$

(*d*)—Substituting these figures in formula (15) the moment of resistance of the section is found to be :

$$R = (F''_t(h_y - z) + (f'_m bh_x \tfrac{2}{3}h_x)$$

$$= (21{,}825 \times 2{\cdot}52) + \left(\frac{1{,}699}{2} \times 8 \times 3{\cdot}48^2 \times \tfrac{2}{3}\right)$$

$$= (55{,}000) + (55{,}000) = 110{,}000 \text{ pound inches.}$$

As the bending moment is $Wl \div 4 = 110{,}000$ pound inches the condition $M = R$ is satisfied.

Similar calculations applied to tests Nos. 2, 3 and 4 in the table give the results in cols. 2 and 5 of the following table :—

Table (b)—Area of Reinforcement and Height of Neutral Axis for Beams in Table (a) calculated by the Author's Formulæ.

No.	Reinforcement.		Load at Failure (Central).	Calculated Height of Neutral Axis.
	Area Sq. In.	Height from Bottom.		
		In.	lb.	In.
(1)	·606	2	5,500	4·52
(2)	·650	1	7,300	4·12
(3)	1·162	2	10,250	4·45
(4)	1·138	1	12.000	3·93

The percentages of reinforcement in Table (*a*) are: 1 per cent. $=0{\cdot}64$ sq. in., and 2 per cent. $=1{\cdot}28$ sq. in. Hence it will be seen that the areas of reinforcement in Table (*b*) are fairly in agreement with those of Professor Hatt. The calculated heights of the neutral axis differ considerably in the two tables, but it is easy to prove by the aid of formula (15) that the positions stated in Table (*b*) are such as are necessary for limiting compression in the concrete to the calculated values given in Table (*a*).

APPENDIX II.

For the construction of concrete-steel beams some engineers employ concrete in the proportions of 1 part Portland cement, 2 parts sand, and 4 parts washed gravel, or clean broken stone; others adopt the proportions of 1 : 3 : 6, with similar ingredients.

Tests made with the object of determining the compressive strength of concrete give extremely variable results, which appear, within certain limits, to depend quite as much upon the age of the concrete and the care taken in its preparation, as upon the actual proportions of the constituents. Taking averages, however, it may be safely said that 2,500 lb. per square inch represents the ultimate compressive strength of 1 : 2 : 4 concrete at the age of two or three months, and 2,000 lb. per square inch the ultimate compressive strength of 1 : 3 : 6 concrete at the same age.

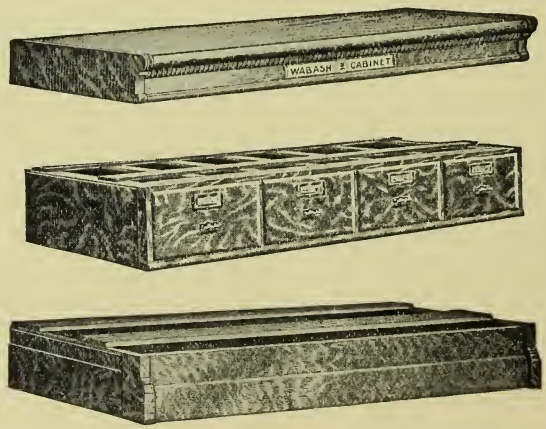
Comparatively few tests of the tensile strength of concrete have been made, but examination of available data indicates that the ultimate tensible strength of the two qualities of concrete mentioned above may be taken at 250 lb. and 200 lb. per square inch, respectively.

CARD INDEXING AND FILING.

By J. Charles Osborne
(Of the Rockwell-Wabash Co., Ltd.).

[Read May 4th, 1905.]

The great advantage possessed by card systems for record-keeping of any kind is the mobility of its units, the ease and thoroughness with which they may be indexed, and the great facility they possess for easy reference. In ancient times the Assyrians had their baked clay cylinders, the Egyptians their papyri, and the Romans their wax tablets—all mobile units. Then came the age of book-making, with their immovable bound leaves, and progress ceased as far as record-keeping was concerned. Books are all right in their place, but for indexing, filing, and record-keeping they have one obvious disadvantage—their units lack mobility.



You have all probably seen the blank index book, ingeniously spaced out with vowel sub-divisions to meet the needs of an alphabetical list, due proportions being observed by varying spaces between the different letters, according to the frequency with which they occur. How satisfactory everything seems until gradually a space here and there fills up, and it is necessary to encroach on the space allotted to other letters: congestion and confusion are the result. A new start is made,

with greater spaces, when a new book is opened, but it leads to the same result. It is then the thought comes: all would be well if only the pages were free instead of bound, additions would then be an easy matter.

In card systems it is possible to add new records at will, irrespective of when or how they are received, and have them indexed in absolutely correct order. It is also possible to eliminate obsolete information at will, without mutilating or re-writing any other record that it is desired to keep, and you may increase and extend the records indefinitely, as there is no limit to the number of drawers you may add to your system, and it is only necessary to extend the cards from drawer to drawer to accommodate additional records, still without the necessity of re-writing a single one.

Card systems consist of a series of cards, filed in a drawer or drawers, held in an upright position by a block called a follower, that moves backwards and forwards, according to the quantity of cards contained therein, so, regardless of the number, they are held in proper position for ready and immediate reference.

The cards containing the records are divided by other cards bearing tabs, that project above the body of all the cards about one-quarter of an inch, and on that tab is printed or written the alphabetical, chronological, geographical or subject index that is to indicate what information is filed under it, thus enabling the user to immediately locate any record desired.

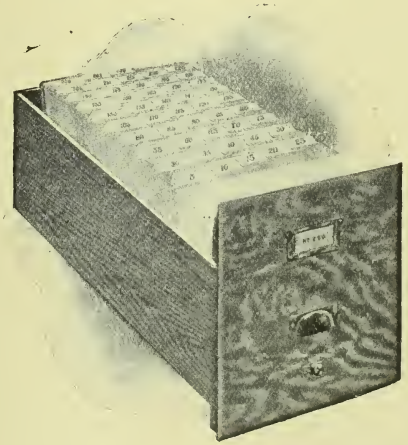


Fig. 1.

A necessary adjunct to all office equipment is a properly devised letter filing system, and as some of the applications I shall treat of to-night embody the filing of documents, etc., I

should like to call your attention to the vertical letter file (Figs. 1 and 2), which is conceded to be the best, under most all conditions, for manufacturing and engineering purposes.

Fig. 2

As with the cards, this consists of a drawer or drawers, fitted with a follower block, in which are placed a series of guides and folders. The folders are numbered consecutively, and are divided by the guides, numbered in multiples of ten. The most perfect arrangement of this method is that shown here, where seventh-cut tabs are used on both guides and folders, allotting the first two positions to the guides, which are red, and the other five positions to the folders, coloured buff; this arrangement enables the user, if he wishes to locate folder number 57, to glance down the red guides to number 50, then immediately adjacent to that, and just as prominent, is the number of the tab on folder 57.

With this method of filing, each correspondent or subject is given a folder, and everything pertaining to that particular correspondent or subject; letters received, copies of letters sent, *orders*, *copies of invoices*, specifications—in fact, everything pertinent to the matter in hand—is placed in that folder, so that in consulting the papers relating to any one subject, they are all together, *obviating the necessity of going to several receptacles*, bundles, letter books, etc.

Many modifications of this system of filing are used. I have seen engineers and others use binders similar to this, and file

papers pertaining to a certain subject in that one binder, then lay it with others, one on top of another, in a drawer or in pigeon holes. The very evident disadvantage in not having a proper receptacle is the necessity of having to handle and disturb all the folders lying on top of the one desired, whereas in a deep drawer like this, where all the folders are filed vertically, it is only necessary to handle the one folder, which can be located, removed and replaced, regardless of the others, that for the time being, are of no interest.

In considering the many uses to which card systems may be applied, it must be borne in mind that we can only treat the subject generally; it is always necessary to consider the needs

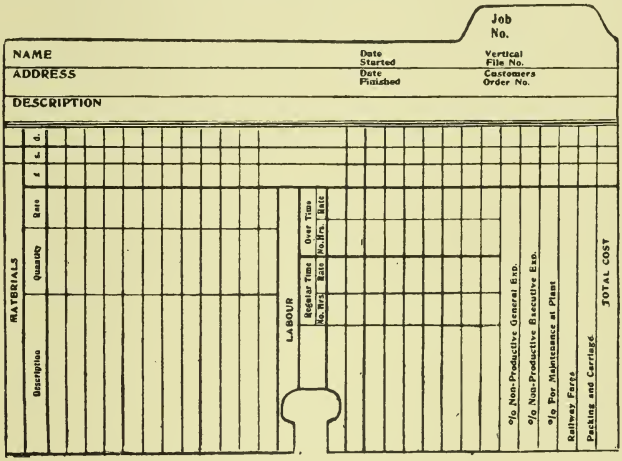


Fig. 3.

of the user and arrange the system to fit those needs, for it very rarely happens that the same methods prevail in two different offices or works, even though the business is the same or very similar. There should be no attempt to make the business fit the card system, but to make the card system fit the business, and while these applications may not just fit, in cases you have in mind, they will serve as suggestions, and, perhaps, in some cases could be adopted with very slight modifications.

As a cost system embodies in its component parts numerous other small systems that may be used alone or in conjunction with each other, I have prepared a few drawings (to be shown when the paper is presented) illustrating a simple cost system that was arranged to cover the product of a firm of crane and derrick builders near Manchester.

Fig. 3 presents the prime cost of the finished product, and at completion this card was used as a basis for all future estimates and charges against this particular class of work. As you can see, this card provides for the name, address and order No. of the customer, the shop order No., file No., a description of the order, and the cost of all operations and details of the construction of the crane.

These details are secured from a variety of sources, as the other drawings will show.

The card (Fig. 3) bears a tab on which the shop order No. is written. When a job is put in hand one of these cards is made out, and it is filed in its proper numerical order in a drawer, and serves as a guide card for all the secondary cards and slips from which the cost of the construction is to be obtained.

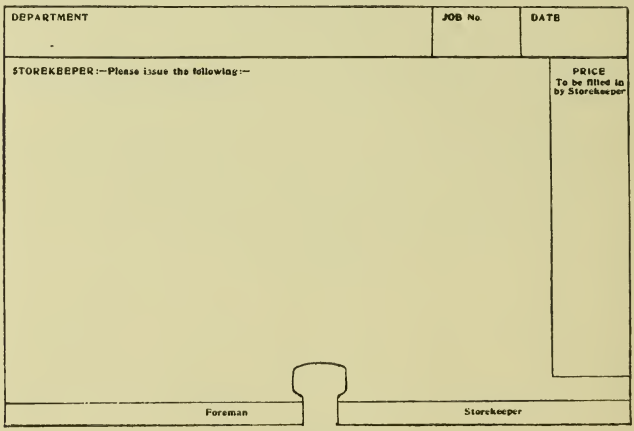


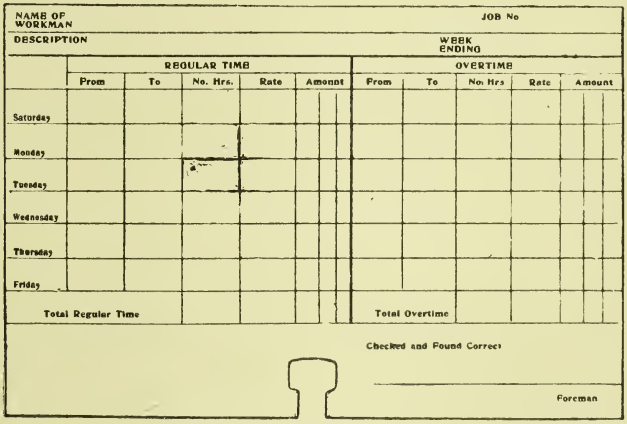
Fig. 4.

The material details are secured from slips of paper—Fig. 4. These are requisition slips, and whenever any material is required for a certain job the foreman makes out, in triplicate, with carbon paper, a set of these forms. He retains one in his book of slips, and sends the other two to the storekeeper, who, after filing the order, signs them, and retaining one as a receipt for the stock, sends the other to the office, where it is filed under card Fig. 3. In this way all material chargeable to the job is gathered together and filed with this card, and allocated at the completion of the order without any re-writing of the various details in books or otherwise.

Time cards (Fig. 5). One card being devoted to each order, are given to a workman when he starts on a certain order. If he makes a full week on the one job that card serves the full time. If he happens to work on a number of different orders he

turns in, at the end of the week, as many cards as he has worked on different jobs. The workman's time is compiled from these cards, so that they serve as a confirmation of the pay roll. Then the cards are filed under their respective orders, and the labour allocated to card, Fig. 3, at the completion of the order, in the same manner as the materials.

When materials are ordered from outside sources the order is made out in duplicate, the original is sent to the supplier, and *the duplicate is filed in the vertical file with all correspondence.* specifications, and other documents pertaining to the order. A plain card is made out bearing the name and address of the supplier, the goods ordered, file No., and date of delivery. This card is filed in a drawer containing daily and monthly guides, under the date delivery is promised. If delivery has not been made by that date this card automatically comes to the attention of the buyer, and he notifies the supplier of the fact, and endeavours to secure delivery, in this way obviating delay, which frequently causes loss and considerable inconvenience on the part of all concerned.


NAME OF WORKMAN

JOB No

DESCRIPTION

WEEK ENDING

	REGULAR TIME					OVERTIME				
	From	To	No. Hrs.	Rate	Amount	From	To	No. Hrs	Rate	Amount
Saturday										
Monday										
Tuesday										
Wednesday										
Thursday										
Friday										
Total Regular Time						Total Overtime				

Checked and Found Correct

Foreman

Fig 5.

When delivery is made, and the invoice is received, this card tells what the material is for, and where to file the invoice, which is required in duplicate, one filed in the folder with other documents pertaining to the job, and the other for use in the counting house.

All goods or materials secured from outside sources are thus posted to card Fig.3 from these invoices at the conclusion of the order.

Returning to the storekeeper, we find him supplied with a stock record on cards like Fig. 6. This shows the name of the article, receptacle, or location, minimum and maximum quantity to be stocked, and all purchases and disbursements, giving date

and order No. of purchases and date, and job No. of all disbursements, preventing all leakage from the stock-room, as all purchases must balance with the disbursements and stock on hand. The copies of the requisitions for materials previously

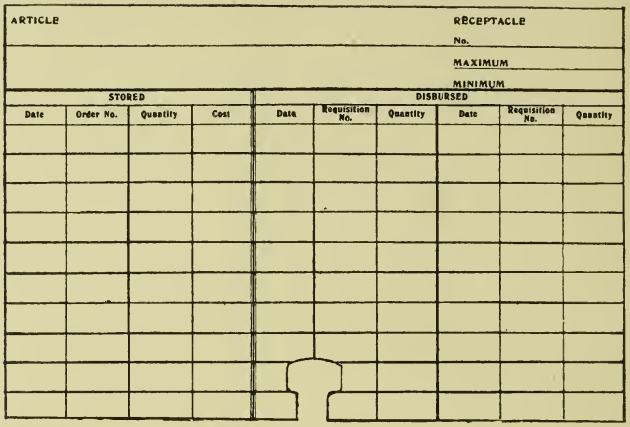


Fig 6.

mentioned held by the foreman and stock-keeper serve as a check against each other, thus reducing the probability of loss through carelessness or any little irregularity in the respective departments, unless there should be collusion between them.

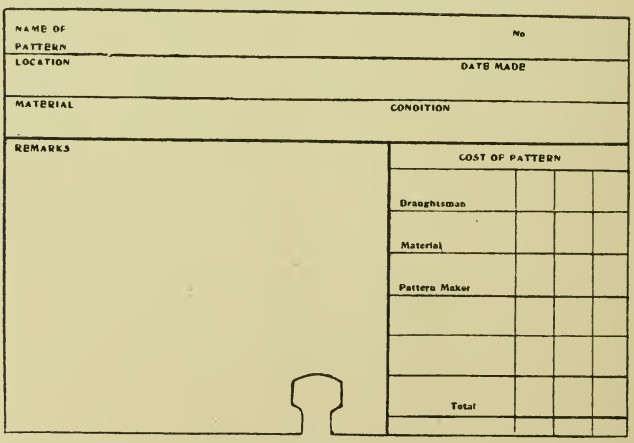


Fig. 7.

A pattern record is part of this system, Fig. 7, giving the name of the pattern, description, number where filed, material it is made of, condition, and the details of the cost of the pattern. A copy of this record is filed under card Fig. 3 for

transmission to that card, and helps to complete the cost. Duplicate copies of this card are made out, one white and one salmon; the white one is filed alphabetically by the name or description of the pattern, and the other is filed by number in numerical order, enabling the user to locate by this cross index any pattern required without delay.

With the records so far secured we have the total direct expense secured from definite sources, but there are other items to be obtained and charged against the job before the cost is completed. As shown on the card these consist of those items of expense that cannot be charged directly to one particular job, but must be divided over the whole product of the establishment.

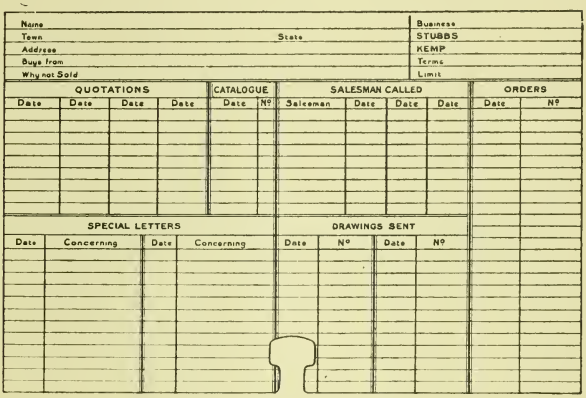


Fig 8.

The expression "non-productive" is a misnomer; a better designation would be simply "General Expenses." This detail consists of the expense incurred by the employment of foremen, helpers, mechanics, firemen, and all that staff of employees whose labour is scattered over the entire product of the plant and who help to make more efficient the efforts of the skilled workmen whose time is definitely charged.

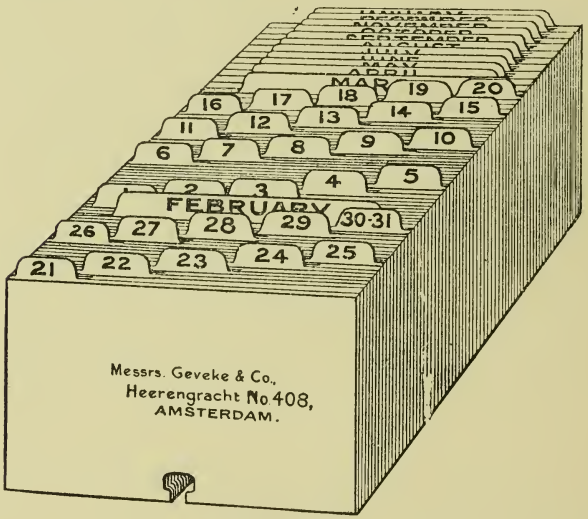
This percentage is obtained in many ways, in the present instance, by taking the total production for a given period and dividing it by the total general expense, this percentage is then charged against each job.

The percentage of executive expense is secured in the same way, and consists of that expense incurred by the employment of managers, book-keepers, clerks, and the rest of an office staff.

Percentage for maintenance of plant provides for general upkeep renewals, rents, rates, bad debts, and all other expense not covered by the two preceding items.

Frequent re-adjustment of these percentages of oncost are necessary to provide for fluctuations in production and expense so as to enable you to use the information obtained to the very best advantage in making estimates.

When the job is finished, and all these secondary records are allocated to card Fig. 3, they are bound together with a rubber band or fastener, and filed in a filled card receptacle in numerical order, where they are accessible in a moment, in case any details of the construction of that particular job are wanted. The main card, Fig. 3, is filed in job No. order in a cabinet on the desk of the manager, who also has a customer's index, alphabetically arranged, giving the name, address, vertical file No., and the job numbers of any work done for them. With this he is enabled,



The Tickler.
Fig. 9.

when he requires their correspondence, to turn up their card and tell the nearest clerk to bring him folder No. 356, No. 754, or whatever it may be, and when it is handed to him everything pertaining to that individual is there. If he wishes to know their address it is not necessary to look up the last letter received, and this card may also contain all information respecting that firm, in a conveniently accessible form.

Other records that this cabinet on the manager's desk may contain are a *record of quotations received.* How often it happens that samples are shown and prices are given that appeal to the buyer. As he is not in need of those goods at the time, he lays the traveller's card on one side and thinks, "I will remember that firm when I want some of that." Yet when the time comes

it may occur to him, "Who was that fellow, and what were his prices?" He has forgotten, whereas if the record appeared under a guide card, indicating the article for sale, he could take advantage of those prices, and perhaps buy at a closer price than he would be able to otherwise do.

Quotations given (Fig. 8), if filed under the name of the firm they are sent to, will often save a lot of time when writing subsequent letters in answer to enquiries regarding same.

What is called a tickler (Fig. 9) is a necessary adjunct to every manager's equipment. This consists of a set of guides, containing the months of the year printed on them, and one of more sets of daily guides. You note on a slip of paper or card any appointment, call or other item that is to be attended to at any future date. File it under the guide card representing that date. On the morning of the current day you remove the guide card of the previous day, and let it take its successive position,

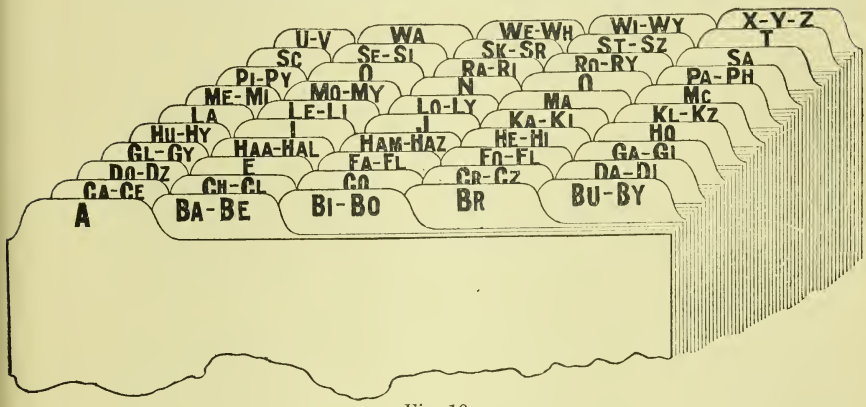


Fig. 10.

following the last daily guide in use. This exposes to view all the matters to be attended to on that day, and if any of the notations are postponed for any reason it merely means filing it under the later date without re-writing or any other trouble. So we have in the tickler a mechanical memory, that absolutely prevents the user forgetting anything, unless he deliberately, with malice aforethought, determines to forget.

The cards lend themselves very advantageously to the indexing of catalogues. How vexatious it is when you wish to consult one or more catalogues respecting certain goods desired, to have to fumble through a miscellaneous heap of books, pamphlets, leaflets, etc., wasting time and temper.

A few cards, arranged alphabetically (Fig. 10), in two colours, one for the subjects treated, and the other for the names of the firms, with a set of vertical file drawers, obviate all this difficulty.

Each catalogue or leaflet is labelled with its number, and the number of the drawer it is to occupy, as there are various size books and sheets to be cared for; various size drawers may be procured to accommodate them, all building up into one cabinet;

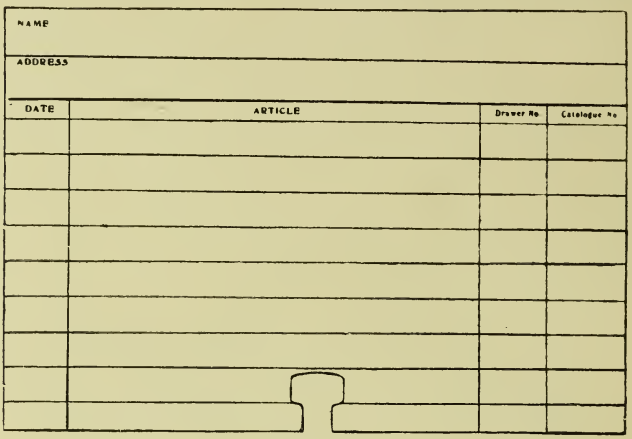


Fig. 11.

the books being filed between guide cards, numbered in multiples of ten, and the leaflets in folders, numbered the same way, so no matter how small or flimsy the sheet may be, and some price lists are very much so, they are perfectly secure, and there is

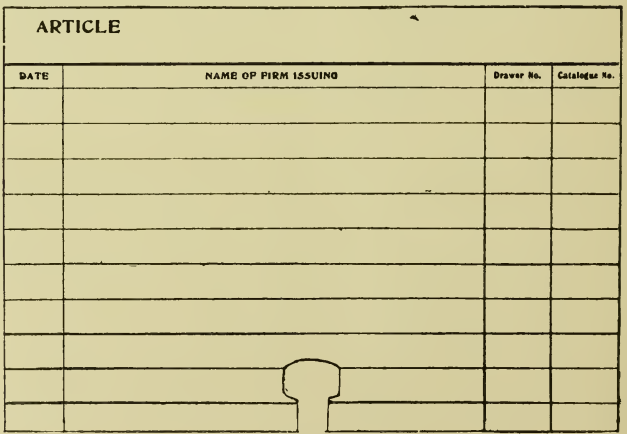


Fig. 12.

little chance of losing them. It is therefore an easy matter if the user wishes to consult the catalogues and price lists of John Smith & Co. By turning up their card (Fig. 11) they can

see that their catalogues are 19 and 75, drawer "A," and 115, drawer "B," securing them immediately, or if they wish to compare the prices of various makers of steam valves, or simply wish to locate some one maker of steam valves, they turn to that subject card (Fig. 12) and the information desired is there.

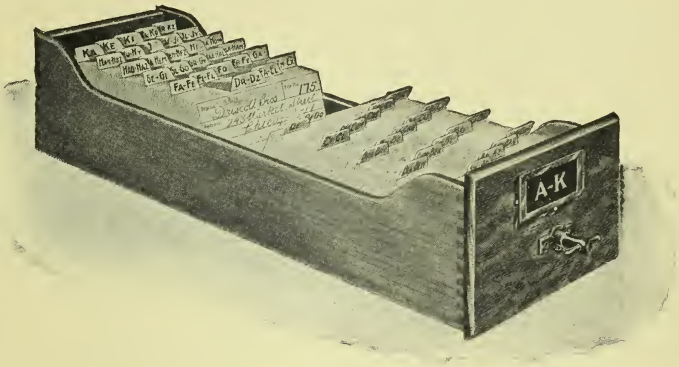


Fig. 13.

Cards Filed under Alphabetical Sub-Division.

One of the first uses to which card systems were put commercially was for "follow-up" systems. By this is meant following-up an enquiry or possible purchaser, as long as there is a chance of securing any business from him. Sometimes a man writes to you, asking for an estimate. You reply, and then in the hurry and rush of business you forget all about it. A week or two later it suddenly occurs to you that you have had no reply to your estimate. You write and find that he has placed his order with someone who gave him a little closer attention. Now, the follow-up system won't let you forget, for one of its principle features is the tickler that I called your attention to a few moments ago.

Figs. 14 and 15 illustrate what I have found to be an ideal card for the follow-up system. On the front, at the top, appears the name and address of the client, with any other details required. The balance of that side is devoted to a record of the correspondence. On the back is a place for quotations and orders, so that this card contains a history of your business relations with that particular individual.

The tickler is used in connection with this system, and constitutes the memory which enables the user to give consecutive attention to the possible client or customer, and obviates the necessity of handling anyone except the individual who requires attention on any particular day.

As an example we will suppose that William Jones & Co. write for a catalogue of our productions on April 8th. We have never been in touch with this firm before, so we take a record card, inscribe the name and address of the applicant, with the number

NAME: Jones & Co BUSINESS

ADDRESS 1901 Heerengracht No 208 Amsterdam

DATE	LETTERS TO	DATE	LETTERS FROM
21/4	Sent Cata No 101	20/4	Send Cata as advertised in
27/4	Advice of Cata arrived safely		Tiger Mag.
30/4	Sent another 101 offered suggestions	29/4	Cata. not yet arrived.
	as to applications	12/5	Are all Sections interchangeable
10/5	Not yet received reply to ours of		Quote for equip. 50000 Medium 6/t
	30th ult.		6 x 4 cards printed 1 side
13/5	All sections interchangeable; stocked	23/5	Will decide in few days
	in oak. May be able to begin	1/6	Ord. No A. 3097
	with small equip.	10/6	Goods arrived quite satisfactory
22/5	May we enter order?	11/9	Ordered 10000 No 264 Cds 6/6 to be
29/5	Not yet favoured with order		shipped 30 days.
2/6	Ack. order. Ship 10 days.		
	Smaller quantity increase cost of		
	printing 6/ per thousand.		
15/6	Advised of shipment		
3/9	Are you yet ready for		
	balance of equipment		

Fig. 14.

of the file we intend to devote to his use, and in the date column headed "Letters From" we note the date of his letter, "April 8th," and in the particulars column an extract of his letter, such as "Asked for catalogue." We then note the date his request has been

DATE	QUOTATIONS	OUR ORDER NO.	DATE	GOODS ORDERED	£	s	d
13/5	1 No 17 1 5 0	6318	1/6	1 No 14 Section	1	5	-
	5 " 64 30 12 6			3 " 64 "	18	7	6
	1 " 9 17 6			1 " 9 "		17	6
	1 " 15 15 0			1 " 15 "		15	-
	50000 No 264 Pl Wh 36 5 0			30000 No 264 Pl Wh 6ds	14	10	-
	Ptg 1 side 1 colour 7 10 0			Ptg 1 side 1 colour	3	10	-
	1 No 2000 Alph Sub 4 17 6			1 No 2000 Alph Sub	4	17	6
		9246	11/9	10000 No 264 Pl Wh 6ds	4	5	-
				Ptg 1 side 1 colour	2	-	-

Fig. 15.

complied with, "April 9th," in the column "Letters To," and in the particulars column an extract of the letter sent, possibly "Catalogue No. 4, with prices sent." We then make out a perfectly plain card with the name and address. This is the

"Tickler" card. The record card is filed in its proper alphabetical order, and the tickler card under a date, say five days subsequent, for we should have received an acknowledgment of its receipt by that time. We need not worry ourselves about it in the interval, for the tickler will not let us forget that enquiry, and when the five days elapse, the card reminds us that this man needs our attention; we take up the tickler card, which gives us his name, find the corresponding record card, and if no acknowledgment has been received, the card shows that to be the case, and we write asking if the catalogue has been received, and soliciting an opportunity to quote, submit samples or anything else that will further our chances of doing business with this possible customer, putting the same tickler card forward again to remind us when to give this man continued attention. On the other hand, if he has replied to our first letter, acknowledging the receipt of the catalogues, the record will appear, showing the date and extract from the letter, and in our reply we will have taken the opportunity to suggest the quotation, samples, etc., and, as he has not had an opportunity to reply to that, we place the tickler card under the date when we expect a reply. So the system works on, until we have a chance to quote, the date a quotation is asked for is noted, and the record says, "Quotations asked for," then the date on which we complied with the request, and the record "Quoted, over"; on the reverse side appears the quotation in detail. We then follow along in an effort to land the order, with the same general procedure, never giving the man a chance to forget us or grow cold, and the great advantage of this method of keeping after your customers, and those whom you desire to make customers, is that, while you may have 5,000 or 6,000 names on your list, they are scattered over a long period, and if only 100 names come to your attention on a certain day, the remaining 4,900 or 5,900 may be entirely ignored, and only that 100 requiring attention be attended to; this enables a minimum of staff to handle a maximum of records, and in no other way is it possible to handle enquiries so efficiently.

When the order has been secured the tickler is put forward to a longer interval, and occasional letters sent soliciting further business or reminding the customer of new lines that may interest him, so we never lose sight of him, and he has no chance of forgetting us. The record card is invaluable at all times, as it tells us what particular line of goods our correspondent is interested in, and if an order is received from an old customer, and it should be, as sometimes happens, vague or incomplete in its details, the record card will often supply the necessary information to enable you to fill the order without the necessity of writing back and forth for further particulars.

It was only natural that, as card systems attained such very great success in their use for other records, they should be

applied to the keeping of ledger records. and I shall now describe the card ledger (Fig. 16), and call attention to some of its very self-evident advantages.

We will first consider the alphabetical arrangement, as it is most suitable under a majority of circumstances. In opening the ledger the names or titles of the accounts are written at the head or top of the card in the space provided, with the address, *limit of*

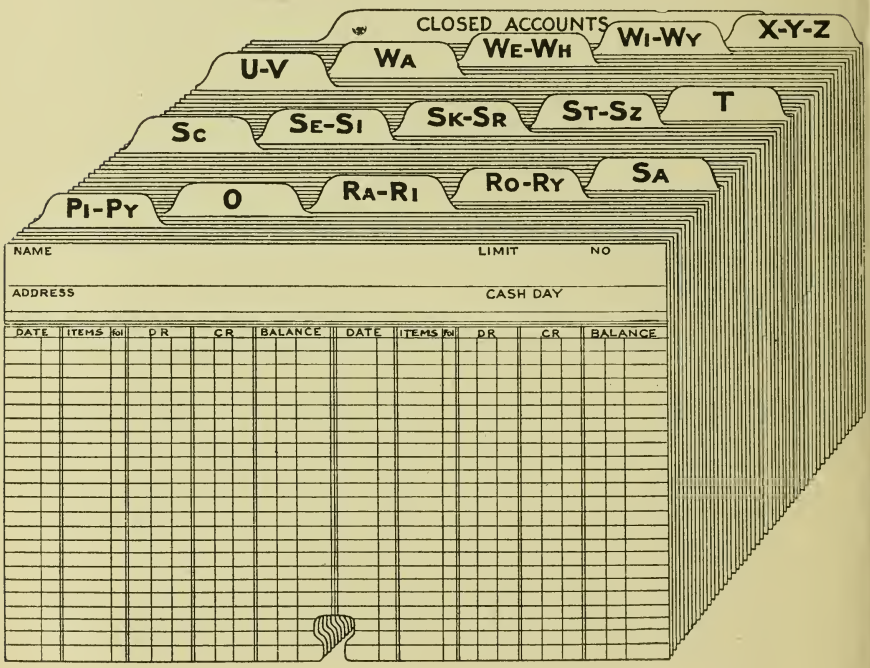


Fig. 16.

credit to be extended, settlement day, and other details of a kindred nature; such entries as are to be made are then written, and the card filed in its proper position, as indicated by the alphabetical guide cards, which are arranged and divided proportionately, as nearly as possible, so each division will have an equal number of cards. This process is repeated until all the accounts needing attention are written up. It is not necessary to transfer any of the accounts from the old ledger, unless it is desired to do so, and then only the balance is brought forward.

The transferring of the accounts from the old to the new ledger is thus accomplished without any extra labour of any consequence.

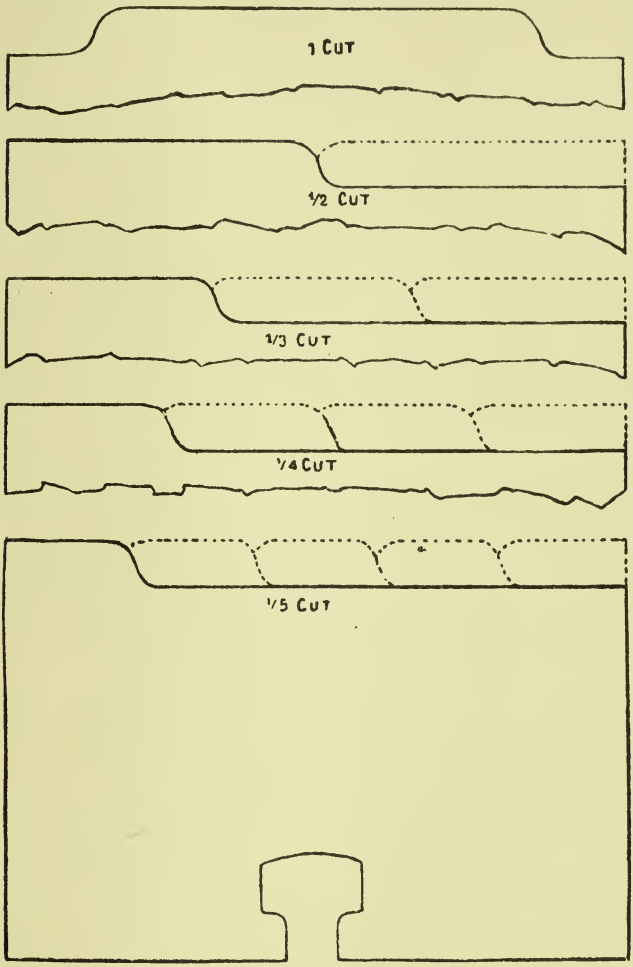


Fig. 17.

Showing the various size Tabs on Guides.

Should the entries on the cards already opened be of such nature that the account is balanced the card, instead of being filed in the "open accounts" division, is placed in the same alphabetical order in the "closed account" division, where it remains until it is necessary to make a new posting, when it is taken out, the posting made, and then it resumes its original place among the open accounts.

You will therefore see that we have at one stroke eliminated the book index, and separated the paid and unpaid accounts, yet the accounts are perfectly indexed, and will remain so in spite of any additions or substractions, every account being in its proper place.

We do not find it necessary to guess how much space to give this or that account, as the elasticity and mobility of the arrangement and index provides for such increase as may occur. When the card is filled, another card is headed, as you would head a page in a book ledger, the filled card is filed away in a filled card receptacle, and the new one takes its place. In this way you have the entire account in one place, and if it should be necessary at any time to consult a particular account over a period of years, you have it altogether, instead of going over a number of books, and perhaps several places in each book.

The elasticity of the card ledger permits of an unlimited increase in the number of accounts without the tedious and expensive process of opening new ledgers, with the attendant writing up of the book index, which is the inevitable adjunct of the book ledger. For if through time the accounts exceed the capacity of the original receptacle, as many drawers may be added as is necessary, and such portion of the cards, with the index, distributed through the additional space. In each instance the index is arranged to suit the maximum number of accounts to be cared for.

Its great flexibility makes possible any classification or accounts into districts, journeys or other arrangement as may be desired, each perfectly indexed to suit special circumstances, and should any different arrangement be required at any time, it can be effected without re-writing a single account.

The numerical arrangement differs somewhat from the alphabetical, and, as shown here, each card is numbered and filed in numerical order, regardless of the alphabetical sequence of the names of the accounts.

They are usually arranged in series of tens, separated by guide cards, which indicate the various tens and hundreds, the cards themselves having tabs bearing the numerals, 0—9, the last figure in the number corresponding with the number on the tab; in order to find the card No. 164, we go to the blue guide card No. "100," then to the buff guide card No. "6," then to the card with the tab No. "4," which is the one required.

This system involves the use of an auxiliary card index, alphabetically arranged, which gives the name, address, financial report, etc., as well as the number of the account, which never changes, for when card No. 164 has been filled, and it is necessary to allot another card to that account, one bearing a No. "4" tab is used, and becomes, in its turn, card No. 164.

The size of the card to be used is governed entirely by circumstances, ranging from a 5 in. by 3 in. to whichever size may be

required. One large firm have an extensive system, and use 5 in. by 3 in. cards; others use 6 in. by 4 in. cards, where the number of entries to each account are few and far apart, but the great majority find the 8 in. by 5 in. size most suitable, this, however, not being arbitrary.

The ruling of the card is always much in accordance with the special requirements, a proper regard for the utilisation of the card space giving the best results. The smallness of the card, as compared with the size of the book ledger page, suggests the thought that it is not possible to have more than a few entries on each card, but when I tell you that it is possible on a card of this size (8 in. by 5 in.) to get 108 debit and 108 credit entries, you will see that it has an equal, if not greater capacity than a page in an ordinary ledger.

In considering the many arguments for and against card ledgers, it should be borne in mind that in the functions which it performs, this system differs in no sense from the ordinary form of book ledgers, the postings are derived from the same source, the difference being that the accounts are kept on cards, filed in a drawer or drawers, instead of on the leaves of a bound book.

The American Business and Accounting Encyclopædia says :— "The object of all systems of accounts is to exhibit the result of the transactions of the business during specified periods, arranged

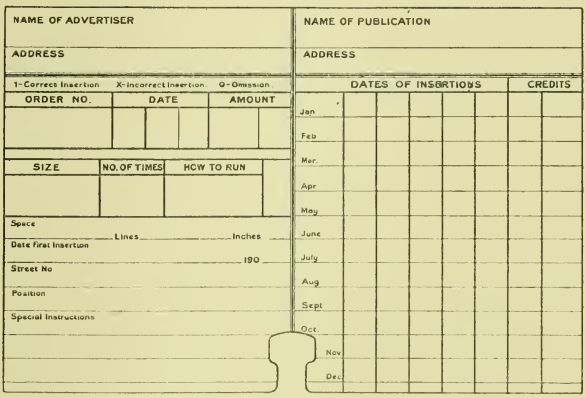


Fig. 18.

A Form of Advertising Record.

in such manner as to inform the proprietors of the business of the amount of revenues, and how they have been produced, the amount of expenditure and their details, and the net income remaining. The best system of accounting therefore is the one which will furnish these particulars in the clearest possible manner, with the smallest possible expenditure of time and labour."

This, we know, the card ledger does, as the advantages to be derived from this method of account-keeping are many, all tending in the same directions—the reduction of expense, and the increased efficiency of the staff.

The first item to be considered under this head is naturally the increased amount of posting which can be done, as practice has demonstrated fully that 50 per cent. more postings can be made under otherwise equal conditions.

The reasons for this are that all the cards under an alphabetical arrangement are self-indexed, the account itself being found in the same or less time than it would take to find the name in the ordinary index, which is thus rendered unnecessary; that the cards, being of a size which enables them to be handled quickly, permits them to be placed close to the items being posted, oftentimes on the page or sheet itself, practically eliminating the possibility of error in the transfer, and materially diminishing the time consumed. This also makes it much easier to write up on the card as it lies flat on the desk or table, the writer being in a natural and comfortable position it is possible to do more work with less exertion than with any form of book ledger.

It is also quite difficult to write at the top and bottom of the page in a majority of book ledgers, and the writing spaces being far apart, much time is wasted in referring from one book to another, or necessitating the employment of two persons, one to make the entries, and the other to call back the items. The size of the books are the cause of a large amount of manual labour being expended in handling them, some ledgers being exceedingly cumbersome and heavy.

The next important item is the rendering of statements of accounts. The fact that all paid or closed accounts are removed from the active ledger as soon as they are balanced renders it entirely unnecessary to handle any account which is not required. Thus it is obvious that if all paid or balanced accounts are removed from the active ledger, and it is unnecessary to handle or examine them, the time usually spent in this task will be much lessened. The number of balanced or closed accounts is usually in a ratio of two, three or four to one, and taking the average as being three to one, and the number of accounts to be handled at 10,000, it is at once apparent that there will be about 2,500 open accounts, and 7,500 closed accounts, everyone of the latter being unnecessarily handled every time the statements are rendered, as each one must be examined *every time* where book ledgers are used to ascertain whether it is balanced or not.

On the other hand, if the card ledger were in use, just those accounts which were of interest would be in a convenient form, easily accessible and all together.

In this form it would be possible to divide the ledger among as many persons as were available, thereby ensuring the sending out of the statements promptly on the first of the month.

Most book-keepers dread making out the trial balance, simply on account of the labour involved. This aggravation is almost entirely done away with by the use of the card ledger, on account of this elimination of closed accounts. Not the least advantage to be derived from this separation of the paid and unpaid accounts is that it is possible to place before the managing heads of the business all of the paid, or all of the unpaid, accounts, without an instant's delay, and without one moment expended in their separation.

This certainly is a distinct advantage in itself, and if there were no other reasons, would recommend the adoption of the card ledger.

Another important item is the one of facility of reference; in the ordinary book ledger it is possible for but one person to consult the ledger at one time, whereas as many as may wish may consult the accounts in the card ledger without interrupting the work of the ledger clerk.

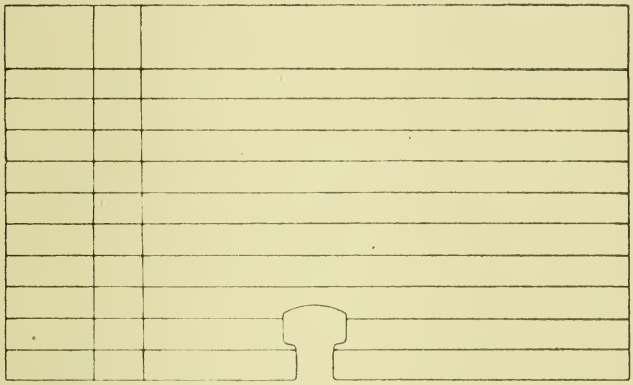


Fig. 19.
A popular Form of Ruling.

It has often been my experience, when demonstrating the card ledger, that the principal would send for one of his ledgers in making comparisons of the rulings, etc., between the books and the cards, and the ledger clerk would put his head into the office every few minutes, asking if he were through with it, as he was standing around doing nothing, and continued to do nothing until the book was returned to him. And that condition often occurs, for a principal frequently wishes to consult an account, and when doing so, he interrupts the work of the clerk, whereas, if the card ledger is used, the one account is called for, and the clerk continues his work with the balance of his ledger.

I will now take up the one objection which seems to be the bugbear of almost everybody—the loss of cards. This seems to be the one thing that first suggests itself, and seems to be about the only objection to the use of the system. The argument

offered is that the looseness of the cards lends itself to manipulation from dishonest motives, and that it would be possible to substitute a card bearing false entries in place of one which shows the correct entries. To those who have not given the subject any consideration, this might seem to be an insurmountable objection, but it will take but a moment's thought to demonstrate that it is as impossible to do this with any greater success than if the entries in the book ledger should be falsified.

If the ledger entries are incorrect, the books will certainly be out of balance, and when they are checked back—as they must be—the abstraction will at once be detected; the result would be just the same as though an error had been made in posting.

It has been said many times that the cards will be misplaced, and the account become lost, but it seems reasonable to suppose that any person who is intelligent enough to keep a ledger could surely be trusted to care for and file a set of cards, and I can assure you that in practice, with the most ordinary care, they are not lost or misplaced, as every one of the well-satisfied users testify.

There also seems to be some fear that the Courts would not accept a card ledger account as evidence, and I unhesitatingly assure you that such is not the case. Everybody knows, who knows anything about accounting, that the ledger record is only corroborative evidence as proof of a transaction, the receipt of the order and delivery of goods must be proved to make a case, and I have been told by accountants and principals of firms that while they have taken ledgers to Court in anticipation of their being required, they never knew of an instance where they were called for.

An instance came to our notice some time ago where one of our customer's was unfortunate enough to have a fire in his establishment, and as he informed us, the premises were practically destroyed, at least, all he could save of his records were his book ledgers. In attempting to collect those accounts still outstanding he was obliged to sue some of them, and the result was that the court held that his book ledger was *no evidence*, and that he must prove delivery, etc., which it was impossible for him to do.

The expense of maintenance is an important item to be considered, as well as the initial cost of installation.

Possibly you have not realised the fact that every time a new set of book ledgers is produced 75 per cent. of the expense incurred is for binding, and the other 25 per cent. for the useful portion of the book; further than that, from 25 to 50 per cent. of the space in the book is wasted, as it is impossible to pre-determine the space any account will require.

On the other hand, with the card ledger, every line of space on the card can be utilised—the card remaining in the system until it is completely filed.

The maintenance expense, therefore, simply consists of the cost of the new cards necessitated by the new accounts opened or additional cards required by the large accounts, for the cabinet, which constitutes the binding, is a permanent fixture, and never has to be replaced.

In closing, I would appeal to you, gentlemen, to use up-to-date and efficient machinery in your offices as well as your works; you would not think of using home-made or make-shift lathes, cranes or engines in your works, yet I have seen firms use tin cake pans as receptacles for card index systems, and then complain that the system was a failure. Your executive departments require as much care in their equipment as the productive departments; and these systems, properly applied, will save time and make more effective the efforts of the principals and staff, upon whom the destiny of the business devolves.

ANNUAL REPORT OF THE COUNCIL

FOR THE

46th SESSION 1904-5.

Presented to the Annual General Meeting, held in Caxton Hall, Westminster, on Thursday, 4th May, 1905.

The Society has again had a prosperous year, particularly from the financial point of view, the excess of revenue over expenditure being by far the largest there has been during the last ten years. Twenty-four new members have been elected, seven have resigned, three names have been struck off the list, and we regret to have to announce the death of two of our honorary members, Prof. Robert Kerr and Sir Isaac Lowthian Bell, so there is a net increase of twelve in the total number of members, which is now 147. This number is not only considerably in excess of what it was until some three years ago, but is a record.

Among the improvements introduced this Session we may mention that the Society has again been enabled to resume its former policy of having all papers printed and circulated to those who apply for them before the meeting, and in presenting about thirty copies of the papers to the author. It is also continuing to print and distribute the Transactions, and has bound a large number of volumes of the technical papers.

Another old custom which has been revived this Session is to provide tea and other refreshments for the members before each meeting. This is ready at 7.30 p.m., and the meeting commences at 8 p.m. This gives an opportunity of friendly intercourse and good fellowship between the members, which it always has been the object of the Society to promote as much as possible.

The visits to works made during last summer were exceptionally well attended and very interesting. It has been found by experience that most of the members are unwilling to give up their Saturday half-holiday for such excursions, but that they are generally able to spare some other time in the week once a month, and by taking advantage of this the usefulness of these visits has been greatly increased.

The following is a list of the visits :—

Date. 1904.	Works seen.	Engineer.
Feb. 21st ..	Kingsway Shallow Tramways.	Maurice Fitzmaurice, M.I.C.E.
July 2nd ..	New Vauxhall Bridge Works.	Maurice Fitzmaurice, M.I.C.E.
,, 16th ..	New War Office and other Government Buildings in Whitehall.	First Commissioner of H.M. Works, &c.
,, 28th ..	Wicks' Rotary Type Casting Co.	E. G. Tottle, A.M.I.C.E.
Aug 12th ..	J. Simpson & Co's Hydraulic and Engineering Works.	L. Simpson, A.M.I.C.E.
,, 25th ..	David Kirkaldy & Sons Testing and Experimenting Works.	W. G. Kirkaldy, A.M.I.C.E.

With regard to the Winter part of the Session, the President and Council still regret that the attendance at the reading of the papers leaves so much to be desired, and would earnestly press upon the members the importance of taking greater interest in this vital part of the Society's work. The papers read throughout have been of a very high standard, and the discussions have been most interesting.

We still regret that owing to insufficient membership it has been found impossible to publish the discussions on the papers, but we feel sure that as the work done by this Society becomes better known the membership will increase, and it will then be possible to publish the discussions, together with the papers.

In the papers that have been read the following subjects have been considered :—

(1) Presidential Address, by Mr. C. T. Alfred Hanssen, A.M.I.C.E., "The Effect of Patent Law on Modern Civilization," in which the author drew attention to the analogy between the position of a landowner and a patentee, and pointed out the injustice of granting the former what might be called an everlasting patent without patent fees, and the very fullest protection legal acumen can device, while the latter obtains only fourteen years protection on most uncertain and onerous conditions.

(2) "Notes on Portland Cement," by Herbert E. Bellamy, which gave a fair summary of the modern requirements for Portland Cement, elicited a valuable critique from Mr. H. W. Anderson, a most interestiug discussion, and some correspondence in the technical press.

(3) "Thames Barrage," by Mr. James Casey, M.I.N.A., who, the Council regret to say, has since died.

(4) "The Mechanics of Flour Milling," by Alfred R. Tattersall.

(5) "Engineering Expert Evidence," by Mr. James F. Reade, A.M I.C.E., which caused a vigorous discussion and some correspondence.

(6) "The Design of Concrete Beams," by Mr. Noble Twelvetrees, M.I.M.E., M.R.S.I., A.M.I.E.E., giving the latest experience and valuable formulæ for the design of reinforced concrete beams which have lately been used with much success for fireproof floors and many other purposes, The discussion was very exhaustive and interesting.

(7) "Card Indexing and Filing," by Mr. J. C. Osborne. A most important subject for all engineers, especially manufacturers and contractors.

The finances of the Society are in a very satisfactory state, as shown by the Balance-Sheet published with this Report. The Society owes a debt of gratitude to its energetic Hon. Secretary, Mr. A. S. E. Ackermann, B.Sc.(Eng^{s}), A.M.I.C.E,, and also to the patient industry of its Hon. Treasurer, Mr. C. T. Walrond, A.M.I.C.E., and the Auditor, Mr. R. L. Matthews. They have during the last seven years re-organized the Society, and we trust that in the near future it may occupy the position due to its age, and to the many excellent engineers who have laboured for its welfare.

We feel sure that if the members would realize that they are members of an old-established Society which has done excellent work, and which through their loyalty will be able to do far better work in the future, we should fully secure their co-operation in attaining this end, and they will find that work done for the Society will not only benefit the members as a whole, but also both directly and indirectly those workers themselves.

On behalf of the Council,

(Signed) C. T. ALFRED HANSSEN.

LIST OF OFFICERS

FOR THE SESSION 1905–1906.

Elected at the Annual General Meeting held in the Caxton Hall, on Thursday, 4th May, 1905.

President.—W. B. Esson, M.I.C.E., M.I.E.E.

Vice-Presidents.

E. Ault, M.I.M.E., F.S.I.

W. Noble Twelvetrees, M.I.M.E., M.R.S.I., A.M.I.E.E.

Members of Council.

A. W. Ackermann, A.M.I.C.E., M.R.S I.

H. Adams, M.I.C.E., M.I.M.E., F.S.I., F.R.S.I.

A. Marshall-Arter, A.M.I.C.E.

E. H. G. Brewster, A.M.I.C.E., M.I.M.E.

B. B. Dadley, A.M.I.C.E.

G. E. Eachus, M.I.C.E.

C. T. A. Hanssen, A.M.I.C.E.

W.W. Hind-Smith, F.R.G.S,. F.R.C.I.

H. Shaw, A.M.I.C.E., M.R.S.I.

H. V. F. Valpy, M.I.C.E.

C. T. Walrond, A.M.I.C.E., M.R.S.I., A.M.I.E.E.

Officers.

Hon. Treasurer.—C. T. Walrond, A.M.I.C.E., 47, Victoria Street, S.W.

Hon. Secretary.—A. S. E. Ackermann, B.Sc.(Eng$^{g.}$), A.M.I.C.E., 25, Victoria Street, S.W.

Hon. Solicitor.—R. H. Willcocks, LL.B., 4, College Hill, E.C.

Auditor.—R. L. Matthews, 13, Nemoure Road, Acton, W.

AUDITOR'S REPORT.

13, Nemoure Road,
Acton, W..
May 3rd, 1905.

The Council,
The Civil and Mechanical Engineers' Society.

Gentlemen,

Having audited the Accounts and Balance-Sheet of the Civil and Mechanical Engineers' Society for the year ending 31st Dec., 1904, I have pleasure in stating that the Balance-Sheet and Revenue and Expenditure Account are correct, and represent the true position of the Society on that date as shown by the books.

The Balance-Sheet shows that the Society has again had a most prosperous year, and before going into the details of the accounts for the year under audit I think it may interest you to have a short comparison between the present Balance-Sheet and those of the previous nine years :—

	£	s.	d.
In 1895 the revised Balance-Sheet showed a deficit of £42 5s. 4d., taking into account an amount of £8 as an asset for office furniture, which had to be written off in 1899, as it was no longer an asset, so that the real deficit has to be taken as .. ... In the above year, nothing stood to Life-Membership Fund or Printing Fund.	50	5	4
In 1896 this deficit had been reduced to £32 10s. 8d., or taking into account the item for office furniture	40	10	8
In 1897 this was further reduced to £12 13s. 7d., with £7 for office furniture, say	19	13	7
In 1899 to £6 6s 9d., with £6 10s. 9d. for office furniture	12	16	9
In 1898 the office furniture was written off, and the deficit stood at	5	5	6
In 1890 this was further reduced to	1	3	5

And in 1901 the balance for the first time stood to the credit of the Society in the sum of ...	10	8	2
Up to this date the Transactions of the Society had not been printed owing to deficiency of funds, but in 1902 the printing of them was re-commenced, and in consequence the balance for that year again showed a small deficit of	1	9	7
In 1903 the Society commenced to bind the volumes of certain technical press, but in spite of this the accounts for that year showed a balance to the credit of the Society of ... ... and this without including the value of the bound volumes as an asset.	7	10	0
In 1904, the year under audit, the balance has been increased to ... ... with a Life Membership Fund of £21, and Printing Fund of £3 14s., so that the actual improvement in the Society's financial position during the period under discussion is no less than £122 14s., an improvement on which the Society may well congratulate itself, considering too that it has been principally achieved during a period of commercial depression, and concurrent with the fact that the Society has been incurring heavier expenses in the direction of printing its Transactions, binding its technical press and improving the quality of its stationery, typing, notices, etc. Furthermore Members' Subscriptions Account now represents an amount that is actually an asset, while much that was brought forward in previous years had to be written off.	47	14	8

Passing to the accounts for 1904, the Members' subscriptions for the year show a total of £110 5s., a small increase over the previous year. £5 10s. 6d. has been paid by Members for the printing of their papers, and £2 14s. 6d. as arrears of subscriptions by a member who had been previously written off as a bad debt. These amounts, with the balance of £7 10s. brought forward from the previous years, form the revenue of the Society for 1904, viz., £126. Of this £18 19s. 7d. is required for printing; £30 7s. 6d. for rent, &c.; £4 15s. 6d. for expenses of Sessional meetings; £12 1s. 3d. for postages, telephone and

sundry expenses; and £12 1s. 6d. written off as bad debts, leaving a balance to carry forward to 1905 of £47 14s. 8d. The amount owing to the Society by Members for arrears on December 31st, 1904, was £39 13s. 6d., and the cash in hand £55 18s. 7d., against which the amount owing by the Society, was only £18 8s. 11d., so that the accounts for 1904 show the Society to be in a very flourishing condition.

I am, Gentlemen,

Yours very truly,

(*Signed*) R. L. MATTHEWS.

UNIVERSITY OF ILLINOIS-URBANA
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TRANSACTIONS
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